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Economic Analysis of Selected Water Policy Options for the Pacific Northwest

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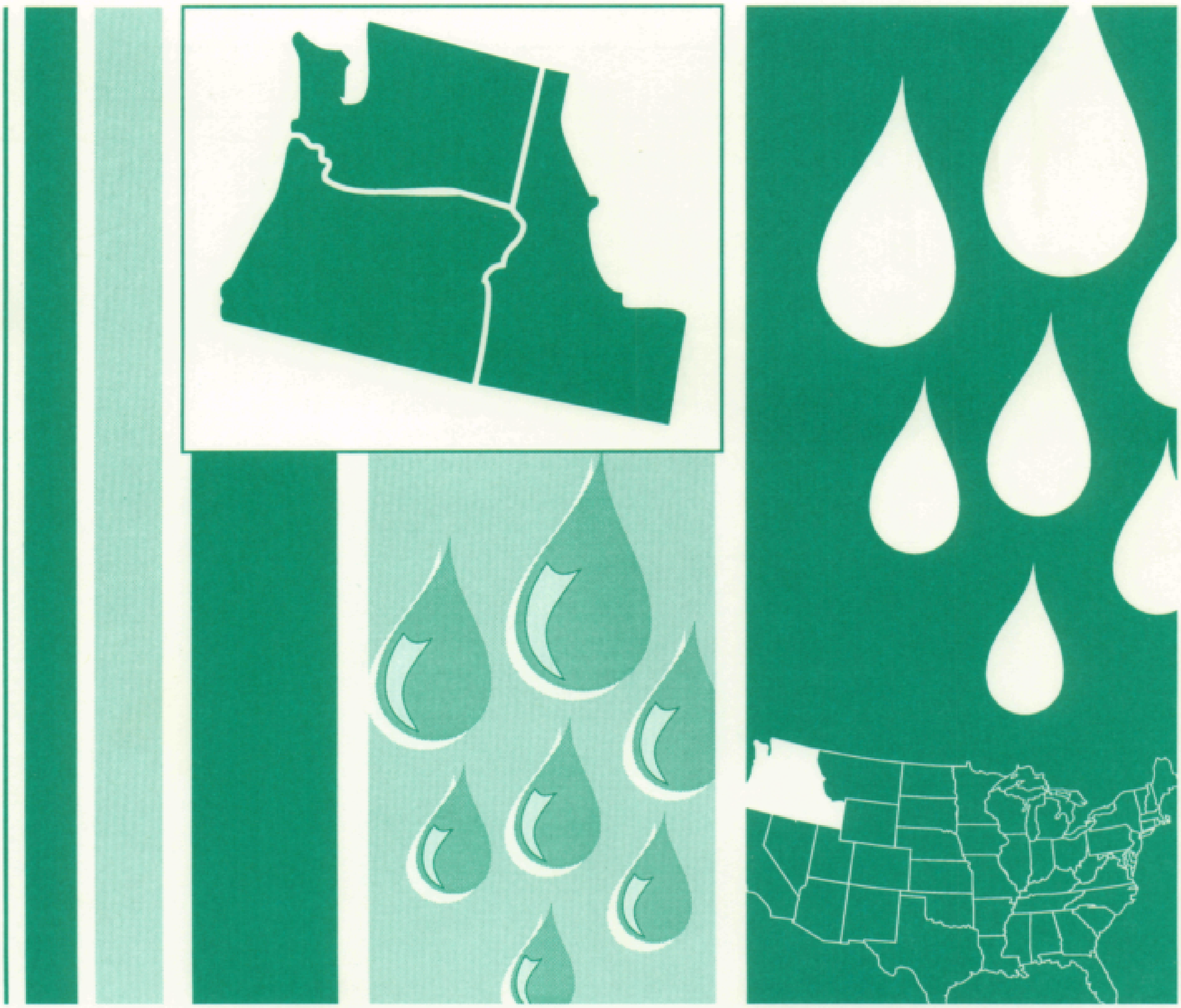

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Abstract

Agriculture in the Pacific Northwest (PNW) could use significantly less water with minimal impact on agricultural economic returns. Less water use by agriculture makes more water available for municipal, industrial, and recreational uses; for improved water quality and wildlife habitat; and for Native American water rights claims. Net water savings up to 18.5 percent of current levels of field crop use can be realized by such actions as reducing Bureau of Reclamation (BoR) surface-water diversion, improving water-use efficiency, and raising the cost of water. Effects on agricultural economic returns for PNW field crops range from a decline of $22 million (1.7 percent) to an increase of $171 million (13.3 percent). Combining different approaches spreads the conservation burden among farmers, water suppliers, and production regions.

Keywords: Water policy, irrigated agriculture, technical change, water diversions, water prices, water use, water reallocation.

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Glossary of Special Terms

Water policy options - Water policy options are defined here as policy reforms that: (1) alter the existing public/private allocation of water resources through statute or legal (court) interpretation; (2) change property-rights institutions that influence private water allocation decisions, for example, water markets, beneficial-use criteria, rights to conserved water, and restrictions on irrigation district economic returns; (3) provide public investment (subsidy) programs that improve water-use efficiency in irrigated agriculture; and (4) alter the level and structure of farm-level prices for publicly supplied water.

Opportunity values - Crop-specific resource opportunity values are the economic returns producers forgo when they choose not to allocate the additional land and water resources required to produce output for another unit (acre) of a particular crop.

Economic returns - Producer economic returns measure gross revenues less variable and fixed production costs and opportunity values (costs) for water and land resources.

Producer welfare impact - Producer welfare impact is the net change in agricultural economic returns for a region due to a particular change in water policy.

Crop consumptive-use requirement - Consumptive-use requirement is the quantity of water needed by a crop for plant consumption during the growing season in order to maximize yield, given its agronomic and climatic environment. These requirements differ across production regions for a crop, and vary from year to year. Consumptive-use requirements increase during heat-stressed seasons, and decrease for cooler seasons.

Acre-foot - An acre-foot of water is approximately 325,851 gallons, or the amount of water required to cover 1 acre of land 1 foot in depth.

Onfarm irrigation efficiency - Onfarm irrigation efficiency for a crop is the degree to which applied irrigation water equals a crop's seasonal consumptive-use requirement less the quantity of precipitation in the crop root-zone available for plant consumption. Crop irrigation efficiencies are unique to field-level irrigation and water management systems. For example, a center-pivot sprinkler system applying 1.8 acre-feet of irrigation water (per acre) to a field of corn with a seasonal consumptive-use requirement of 1.6 acre-feet and 0.4 acre-feet of water from precipitation irrigates at 67-percent efficiency, that is $(1.6 - 0.4)/1.8 = 0.67$. Aggregate crop irrigation efficiency for a region reflects a weighted average of irrigation efficiencies across irrigation systems for a crop within the region.

Irrigation technical change - Irrigation technical change refers to improvements in technology systems that increase water-use efficiency in agriculture. Off-farm technology improvements increase conveyance efficiency by reducing water losses in the delivery of surface water to farms. Improved conveyance efficiency ensures that the quantity of surface water at the farmgate will be closer to the diverted quantity at the point of diversion. Improvements in onfarm irrigation technology and water management increase irrigation efficiency by: (1) reducing applied irrigation water closer to crop consumptive-use requirements adjusted for precipitation remaining in the crop root-zone; (2) improving the timing of water applications, that is, applying water when the plant requires water; and (3) improving the uniformity of water distribution across a field.

Net conserved surface water - Net conserved surface water for a region is total conserved surface water, minus increased groundwater use when ground water is substituted for surface water.

Return flows - Return flows are that portion of irrigation water losses returning to streamflow. Return flows occur through surface drainage and water losses that percolate into aquifer flows contributing to downstream flows.

Summary

Agriculture accounts for roughly 87 percent of water diverted from ground and surface water sources in Washington, Oregon, and Idaho. As the major user of water, agriculture may be asked to do with less as the competition for water intensifies for such nonfarm uses as municipal, industrial, and recreational uses; for water quality and wildlife habitat requirements; and for Native American water rights claims. Agriculture in the Pacific Northwest could use less water with minimal impact on agricultural economic returns.

If farm-level costs of publicly supplied water were doubled, for example, the region could save 959,000 acre-feet of surface water (312 billion gallons), while net economic returns to the region's field-crop farmers would fall by an estimated $22 million (1.7 percent). By contrast, the region could save 554 billion gallons (1.7 million acre-feet) of water, with enhanced onfarm irrigation efficiency plus improved crop yields, and simultaneously raise net returns to the region's field-crop farmers by as much as $171 million (13.3 percent).

The report looks at five policy scenarios, alone and in combination, for their effect on water use and agricultural returns for field crops:

- reduced diversions (withdrawals) of surface water for agriculture,
- increased farm-level costs of publicly supplied water,
- increased efficiency in transferring surface water from the source to the farm,
- increased irrigation efficiency on the farm, and
- increased irrigation efficiency on the farm coupled with improved crop yields.

Any change in the way water is allocated will alter the economic costs of crop production. Changes in the cost structure will induce producers, trying to maximize their total net returns, to shift land and water resources among their crops, to shift from surface water to ground water, to shift between irrigated and dryland production, or to idle cropland altogether. As farmers shift land and water resources, they may conserve surface and ground water, or conserve surface water and use more ground water. Surface water savings range from 0.12 million acre-feet (39 billion gallons) to 1.9 million acre-feet (619 billion gallons) per year.

Farmers' Response, Water Savings Depend on Policy Focus

Reducing allowed withdrawals of surface water for agriculture (5-20 percent) will promote more dryland crop production and increase irrigation of crops that require less water, but with the use of existing ground water supplies. Estimated surface water savings: 0.16-0.62 million acre-feet (52-202 billion gallons) in the Pacific Northwest. Returns to the region's field-crop farmers: down by $2-$9 million (less than 1 percent).

Raising prices for publicly supplied water (10-100 percent) conserves surface water, but encourages farmers to use ground water instead. Estimated surface water savings: 0.12-0.96 million acre-feet (39-312 billion gallons). Net water savings are less (0-0.14 million acre-feet). Returns to the region's field-crop farmers: down by $3-$22 million (0.2-1.7 percent).

Increasing efficiency in conveying surface water from the source to the farm (10-50 percent) assures that water withdrawn actually reaches the farm, but generates no onfarm effects. Estimated surface water savings: 0.4-1.9 million acre-feet (130-619 billion gallons). Returns to the region's field-crop farmers: no change. Onfarm water use remains constant because farmers' water supplies are unaffected.

Increasing irrigation efficiency on the farm (5-20 percent) promotes crop substitution, thereby saving more water than with improved water-use efficiency alone. Estimated water savings: 0.4-1.8 million acre-feet (130-587 billion gallons) of surface and ground water. Returns to the region's field-crop farmers: up by $10-$27 million (0.7-2.1 percent). If yields also improve by 6 percent, returns could rise by $171 million (13.3 percent).

Combining Policies Enhances Water Savings

Combining two or more policy choices induces farmers to respond differently from single policy choices. The report looks at the following three combinations of policy choices.

A general policy mix, evaluated with small and moderate changes, includes:

- 10 percent less BoR water, plus a 20-percent increase in BoR conveyance efficiency, plus a 10 percent increase in onfarm irrigation efficiency with a 2-percent yield increase, and a 20-percent price hike in farm-level costs for BoR water, or

- 20 percent less BoR water, plus a 30-percent increase in BoR conveyance efficiency, plus a 20-percent increase in onfarm irrigation efficiency with a 6-percent yield increase, and a 50-percent price hike in farm-level costs for BoR water.

A resource-efficiency policy mix includes:

- a 30-percent increase in BoR conveyance efficiency, plus a 20-percent increase in onfarm irrigation efficiency with a 6-percent yield increase, and a 50-percent price hike in farm-level costs for BoR water.

A BoR policy focus includes:

- 20 percent less BoR water to agriculture, plus a 30-percent increase in BoR conveyance efficiency, and a 50-percent price hike in farm-level costs for BoR water.

A general mix of policy choices conserves 0.9-1.8 million acre-feet (293-587 billion gallons) of surface and ground water in the Pacific Northwest. Returns to the region's field-crop farmers rise by $59-$160 million (4.5-12.4 percent).

A resource-efficiency policy mix conserves 1.7 million acre-feet (554 billion gallons) of surface and ground water. Returns to the region's field-crop farmers rise by $161 million (12.5 percent).

A mix of choices emphasizing a BoR policy focus conserves 0.8 million acre-feet (261 billion gallons) of surface water. Returns to the region's field-crop farmers decline by $18 million (1.4 percent).

Combining policy choices has advantages by allowing for: (1) balanced policy reform and more moderate policy changes to attain conserved-water goals; (2) water conservation as a shared sacrifice by spreading the conservation burden across producers and water sources, between producers and those delivering water to farms, and among production regions; (3) guiding policy change toward particular regional policy goals, while reducing conservation costs; and (4) promoting a greater public awareness of the increasing scarcity value of finite water resources. Balanced policy reform recognizes the importance of weighing multiple policy goals against the degree of implementation required for each policy choice. Multiple policy goals may include water conservation for enhanced fish and wildlife preservation, enhanced water quality (surface and ground water), better equity in demands (particularly for Native Americans), and sustainable regional agricultural economies.

Policy Choices Affect Policy Goals

Policy choices will differ in their contribution to policy goals. For example:

- mandatory reductions in surface-water diversions, increased water prices, and increased efficiency in water delivery to farms all give greater emphasis to streamflow-oriented policy goals through surface-water conservation, and

- improving onfarm irrigation efficiency enhances policy goals for groundwater quality by also emphasizing groundwater conservation.

Conservation Augments Downstream Flows

Water conservation efforts increase downstream flows during the irrigation season. The amount of flow augmentation depends on the characteristics of underground aquifers, soil permeability, the volume of farm runoff, evaporation losses, and their effects on return flows. However, two factors ensure that policy-induced water conservation augments downstream flow during the irrigation season.

- Conservation policy induces farmers to increase the production of crops that require less water and farmers substitute ground water for surface water, thus reducing crop consumptive-use requirements from surface-water sources.

- Conserved surface water also includes water that would have been permanent loss (from deep aquifer seepage and evaporation), and a portion of irrigation return flow (from subsurface flows) that would not have occurred during the irrigation season.

Conservation Policy May Affect the Livestock Sector

Water conservation policy may also affect the livestock sector. Mandatory reductions in BoR surface-water diversions significantly reduce surface-water irrigated alfalfa. Reduced alfalfa supplies will cause a rise in local alfalfa prices and a decline in returns for the livestock sector. Choices that include improvements in onfarm irrigation efficiency, however, would improve returns for groundwater-irrigated alfalfa and alfalfa supplies, thus reducing the negative impact of regulatory choices on the livestock sector.

Policy of Maximum Conservation Will Require Producer Compensation

If less water is used for agriculture, more water will be available for other (nonfarm) public uses. A policy to maximize conservation, to be successful, will probably require that the public assume the costs of conservation. For if farmers' costs are not fully subsidized, farmers will be less inclined to commit to maximum conservation. Therefore, positive farm returns reported here indicate the total value of conserved water to agriculture and farmers' economic incentive to conserve.

How changes in Pacific Northwest water policy affect farm returns and water use

Scenario	Net agricultural economic returns	Net water savings[1]
	Percent change from current practices for field crop production	
Individual policy scenarios		
1. Reduced diversions of publicly supplied (BoR) water:		
5% reduction	-0.1	1.6
20% reduction	-0.7	6.3
2. Increased conveyance efficiency of publicly supplied (BoR) water:		
10% increase	0	*3.9
50% increase	0	*19.1
3. Increased efficiency of onfarm irrigation:		
5% increase	0.7	3.8
20% increase	2.1	18.5
4. Increased efficiency of onfarm irrigation plus higher yields:		
10% more efficiency plus 2% yield increase	5	7.9
20% more efficiency plus 6% yield increase	13.3	17.5
5. Higher prices for publicly supplied water:		
10% price hike	-0.2	**0
100% price hike	-1.7	**1.4
Combined policy scenarios		
6. 10% less BoR water + 20% increase in BoR conveyance efficiency + 10% increase in onfarm irrigation efficiency and 2% yield increase + 20% price hike for BoR water	4.5	9.4
7. 20% less BoR water + 30% increase in BoR conveyance efficiency + 20% increase in onfarm irrigation efficiency and 6% yield increase + 50% price hike for BoR water	12.4	18.3
8. 30% increase in BoR conveyance efficiency + 20% increase in onfarm irrigation efficiency and 6% yield increase + 50% price hike for BoR water	12.5	17.7
9. 20% less BoR water + 30% increase in BoR conveyance efficiency + 50% price hike for BoR water	-1.4	5.8

Notes: BoR refers to the U.S. Department of Interior, Bureau of Reclamation. Each percentage point change in net agricultural returns averages $13 million. Each percentage point increase in net water savings averages 100,000 acre-feet (32 billion gallons).
* = As a percent of BoR water diverted for field crops, these water savings range from 9-46 percent.
** = Saved BoR surface water for this scenario ranges from 3.7-31.2 percent of BoR water delivered at the farmgate for field crops, which amounts to 30,800 acre-feet (10 billion gallons) for each 1 percent of BoR water savings.
[1]Net water savings include only surface water for scenarios 1 and 2; surface water and ground water for scenarios 3, 4, 6, 7, and 8; and surface water savings less increased groundwater use for scenarios 5 and 9. Percentages for water savings measure net water savings relative to total water use for field crops.

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Water: A Resource Conservation Policy Issue

Water scarcity in the Western United States has intensified in recent years, resulting in increased economic and political pressures for water policy reform. Increased values of water for competing uses offer opportunities to ensure greater economic efficiency in resource allocation, while enhancing the availability and quality of public goods. Recent Western drought conditions have accentuated water scarcity problems. Municipal, industrial, and recreational demands for water have increased due to regional population and economic growth. In addition, broader public concerns about water quality, fish and wildlife habitat, and Native American water rights claims are redefining the mission and structure of water management institutions. Finite water resources, then, must be allocated more efficiently in order to achieve these growing environmental and social policy goals (including sustaining viable regional agricultural economies).

Public concern for endangered species and water quality has increased demands for water flows sufficient to ensure the survival of native species such as salmon. These new demands have realigned economic, political, and environmental forces shaping water policy. Environmental legislation, such as the Endangered Species Act and the Clean Water Act, has empowered Federal and State agencies to impose environmental constraints on traditional allocations of water resources. Agriculture, accounting for roughly 83 percent of water consumption in the West, is the most probable source from which to acquire water resources for competing demands (Wahl, 1989; Wilkinson, 1985; Howe, 1985; Vaux, 1986). However, economic trends in agriculture, under existing water policies, are unlikely to significantly alter agricultural water use. Therefore, regulatory or conservation-incentive water policy will be required to induce agricultural water conservation (Schaible, Kim, and Whittlesey, 1991; Moore, 1991).

The Federal role in water policy is changing from one of resource development to resource management. The Department of the Interior's Bureau of Reclamation (BoR) allocates over 25 million acre-feet (8.1 trillion gallons) of water to roughly 10 million acres of cropland in the West.[1] Fish and wildlife resource values, endangered species protection, and water quality are critical elements of the BoR's 1990 Strategic Plan (U.S. Department of the Interior, 1992b), which emphasizes water conservation and better management of BoR facilities (U.S. Department of the Interior, 1992a). In addition, recent Federal legislation also promotes water policy change. The 102d Congress passed Public Law 102-575, which recognizes environmental values and makes changes in water policy to reallocate water resources in California.[2] The expanding Federal role in water policy reform appears consistent with a mission designed to place greater value on the "environmental quality and ecological integrity of Western river systems" (Moore, 1991).

Water policy reform is judged by its ability to promote conservation of significant agricultural water supplies and by its cost to the agricultural sector. The challenge of Western water policy reform is to promote regional policies that both conserve

[1] The BoR is the Federal agency responsible for implementing the Federal water resource development mission. Agricultural water use supplied by the BoR constitutes 40-85 percent of the annual flow of several major Western river systems (Moore, 1991).

[2] Public Law 102-575, incorporating the Central Valley Project Reform and Improvement Act of 1992, reallocates a minimum of 800,000 acre-feet of Central Valley Project water to enhance fish and wildlife habitat in California's Sacramento and San Joaquin River systems. The legislation also encourages agricultural water-use efficiency by allowing water market transactions, changing water-pricing structures, and increasing BoR water costs.

agricultural water and preserve the character of the regional agricultural economy.

Alternative water policy changes will impose different economic costs on agriculture, involving resource allocation adjustments, input and output substitutions, and production and income adjustments. In addition, policy changes will result in varying secondary, regional economic impacts. With varying regional demands for agricultural water conservation, water policy reform is a regional rather than local policy dilemma (Weatherford, 1982; Shupe, 1982; Vaux, 1986).

This report evaluates the water conservation potential of selected water policies and the consequences of these policies for the field-crop sector of the Pacific Northwest (Idaho, Oregon, and Washington). Analysis is limited to quantity-based regulatory policies and conservation-incentive policies emphasizing resource efficiency. Regulatory policy involves mandatory reductions in BoR-supplied agricultural water supply. Conservation-incentive policies involve increases in farm-level costs for BoR-supplied surface water, and investment (or subsidy) policies to improve BoR water distribution systems and to increase onfarm irrigation efficiency.[3] Finally, several policy options represent a combination of policy choices.

Agricultural impacts in this report include reallocation of land and water among crops; production shifts between irrigated, dryland, and idled cropland; and changes in agricultural economic returns. The level of conserved agricultural water indicates the degree to which policy choices are likely to achieve economic, environmental, and equity goals. All impacts, however, indicate the relative burden that water policy choices impose on agricultural producers, water management institutions, and the public.

Conserved agricultural water embodies both extensive and intensive agricultural water-use changes, depending upon the change in water policy. Traditional engineering-based, representative-farm analysis emphasizes intensive water-use changes, that is, reducing water-use rates to approximate crop consumptive use. Extensive water-use changes include substitution effects across crops, water sources, and production technologies. With changes in water policy, producers may shift irrigated production to less water-demanding crops and to dryland crop production, may use more ground water and less surface water, or may idle cropland altogether. These substitution effects conserve water primarily by lowering aggregate crop consumptive use. Producers substitute resources to account for changing opportunity costs of land and water, and to maximize economic returns.[4]

Policy options are evaluated using an aggregate, multioutput production model of irrigated and dryland field-crop production in the Pacific Northwest. The model uses a primal-dual optimization (programming) approach, wherein implicit, total economic-cost functions are used to identify crop production technologies and economic opportunity costs of allocating fixed land and water resources. Optimal solutions reflect longrun equilibrium producer decisions. These decisions reflect the effects of resource substitution by producers.

Water Policy Context for the Pacific Northwest

Environmental and water quality values will likely influence water-allocation decisions in the Pacific Northwest. Water policy that recognizes these values evolved very slowly, largely because of the perception of abundant water resources from the Columbia and Snake River systems. In addition, major water development projects along these river systems made water resource scarcity an issue only in low-flow years, when the policy debate centered on the need to reallocate water from agriculture to hydroelectric power generation (Butcher, Wandschneider, and Whittlesey, 1986; Houston and Whittlesey, 1986; and Hamilton, Whittlesey, and Halverson, 1989).

Water Policy Focus

The policy debate has been refocused due to heightened concern over endangered salmon in the Columbia-Snake River Basins. Since 1991, the National Marine Fisheries Service (NMFS) has listed Snake River sockeye salmon as an endangered species, and Snake River fall and spring/summer chinook salmon as threatened species under the

[3] Conveyance efficiency is considered off-farm technical change. Increased irrigation efficiency is onfarm technical change, which is evaluated first with constant crop yields and then with yield enhancements, that is, output-enhancing, input-saving technical change.

[4] Producer welfare reflects economic returns to agricultural production for a particular policy environment. Economic returns are gross revenues less variable and fixed production costs, and opportunity costs of water and land resources.

Endangered Species Act (ESA). The NMFS salmon designations recognized the legal obligations within the Pacific Northwest Electric Power Planning and Conservation Act of 1980, and invoked the authority of the ESA. The first Act mandates that the Northwest Power Planning Council consider fish and wildlife uses equal to traditional uses of the Columbia River system and requires that it develop a Fish and Wildlife Program. The ESA requires development of a recovery program for the endangered species. NMFS will address the issue of long-term survival actions (policy) required to recover salmon populations. However, the Corps of Engineers and the BoR, the principal operators of dams, reservoirs, and water distribution systems, together with the Bonneville Power Administration, are expected to implement interim fish recovery measures.[5]

Water-quality concerns have also helped to refocus the water policy debate in the PNW. In 1991, the U.S. Geological Survey (USGS) identified the mid-Columbia River Basin for its National Water-Quality Assessment Program, which examines the primary natural and human factors affecting the quality of surface and ground water. The key water-quality issues for the mid-Columbia Basin include: (1) elevated concentrations of nutrients, trace organic compounds, sodium, nitrates, and bacteria in surface and ground water, which contribute both to human health problems and to deterioration of fish and wildlife habitat; (2) streambed sediment that covers fish-spawning gravels; and (3) insufficient oxygen and elevated surface-water temperatures due to low flows (U.S. Department of the Interior, 1991). The U.S. Department of Agriculture's (USDA) Area Study Project, in cooperation with the USGS, examines relationships between agricultural production and environmental characteristics in the mid-Columbia River Basin.

Finally, USDA's Economic Research Service and Oregon State University researched agriculture's contribution to nitrate contamination of ground water, due to leaching of nitrogen fertilizers. This project assessed the economic and groundwater quality impacts of adopting farm-level best-management practices in southeastern Oregon. Results indicate that adoption of improved irrigation systems, crop rotations, and nutrient management systems will allow the region to meet Oregon's strict drinking-water standards (Kim, and others, 1994).

Consequences to human health and fish/wildlife preservation, and the quality of ground water have made water resource allocations in the Pacific Northwest a significant policy issue. Together with increased municipal, industrial, and recreational demands, and Native-American equity issues, these concerns ensure a broad-based rationale to examine different water policy changes.[6]

Irrigated Agricultural Characteristics

For the Pacific Northwest (PNW), the total economic value of agricultural products sold during 1987 was $7 billion, with 45 percent from livestock production and 55 percent from crop production (table 1). Livestock production accounts for a larger share of the economic value of agricultural output in Idaho than in Oregon or Washington. Lower valued crops, including grains, hay, and silage, contribute 21 percent of the PNW's total value of agricultural products (table 1).

Agriculture in the Pacific Northwest depends greatly upon water. Total crop production occupied nearly 12 million acres in 1987, with surface and ground water used to irrigate 6.4 million acres of cropland and pastureland (table 2). Irrigated cropland alone accounted for 46 percent of harvested cropland in the PNW: 65 percent in Idaho, 43 percent in Oregon, and 30 percent in Washington. The region's irrigated sector produced a variety of products, but 66 percent of irrigated cropland was used to produce wheat, barley, hay, and corn for grain. Irrigated hay production is more important in Idaho because of its

[5] Interim fish recovery measures involve modifications to Columbia-Snake River system operations, designed in the short term to improve river flows (velocities) for juvenile fish migrating downstream in the spring and summer, and to improve late-summer river temperatures for adults migrating upriver. The Supplemental Environmental Impact Statement, invoked by Council on Environmental Quality guidelines for Federal actions, evaluates the environmental effects of these interim measures.

[6] Native American equity concerns in the PNW involve claims to federally reserved water rights. These rights were confirmed by the 1908 U.S. Supreme Court decision in Winters vs. U.S., known as the Winters Doctrine (American Indian Research Institute, 1988). Subsequent judicial decisions have clarified that Indian water rights may include water rights for irrigated agriculture and treaty-protected fishing rights (Folk-Williams, 1982). Indian water rights claims in the PNW have dealt with claims for irrigated agriculture (largely in Washington), but mostly these claims relate to treaty-protected fishing rights and effectively involve maintenance of instream flows for fishery habitat (Folk-Williams, 1982). Equity concerns in the PNW, then, are an additional motivating factor for water policy change that contributes to decisionmakers' ability to "meet the common and interdependent needs of all people" in the PNW and the general public (Deloria, 1985).

Table 1--Value of agricultural products sold in the Pacific Northwest, 1987

State/region	Total	Livestock	All crops	Grains[1]	Hay and silage	Net cash returns[2]
			Billion dollars			
Idaho	2.269	1.172	1.098	0.408	0.120	0.388
Oregon	1.846	.797	1.049	.176	.199	.301
Washington	2.919	1.231	1.689	.440	.131	.478
Pacific Northwest	7.034	3.200	3.836	1.024	.450	1.167

[1]Includes the gross market value for corn, wheat, barley, oats, and other grains.
[2]Net cash returns measure gross market value less total operating expenses. (Total operating expenses did not include allowances for depreciation, changes in inventory values, and property taxes paid by the landlord.)
Source: U.S. Department of Commerce. *1987 Census of Agriculture.* Part 51, Vol. 1, November 1989.

Table 2--Irrigated acres harvested in the Pacific Northwest, 1987

Land use/crop category	Idaho	Oregon	Washington	Pacific Northwest
		1,000 acres		
Total harvested cropland[1]	4,349.0	2,833.0	4,597.0	11,779.0
Harvested irrigated cropland	2,811.0	1,228.0	1,378.0	5,417.0
Irrigated pastureland and other land	408.0	420.0	141.0	967.0
Selected irrigated crops:				
Corn for grain	47.5	16.1	89.9	153.5
Wheat	587.7	122.1	255.9	965.7
Barley	473.4	69.2	41.8	584.4
Hay[2]	846.2	636.8	382.4	1,865.4
Irish potatoes	352.7	58.1	105.5	516.3
Vegetables	37.7	113.2	95.5	246.4
Orchards	12.9	47.8	235.6	296.3

[1]Includes harvested irrigated and dryland cropland.
[2]Includes acres for all hay crops and forages, except pasture.
Source: U.S. Department of Commerce, *1987 Census of Agriculture*, Part 51, Vol. 1, Nov. 1989.

greater reliance on forage production for the livestock sector.

Producers in all three States use water resources to grow higher valued crops, principally potatoes, vegetables, and orchard crops (apples, peaches, pears, nuts, etc.). These crops account for only 14 and 18 percent of irrigated cropland in Idaho and Oregon, but 32 percent in Washington.[7] The greater reliance on lower valued crop production in Idaho and Oregon indicates a regional difference in the relative importance of water resources (particularly for Idaho, which depends more heavily on forage output for livestock production). This difference across States has implications for the appropriate regional water policy mix and the relative burden required for each State in meeting regional water conservation policy goals.

Agriculture in the Pacific Northwest dominates withdrawals of both surface and ground water, accounting for 87 percent of total withdrawals for the region in 1990 (table 3). Agriculture withdrew 35.4 million acre-feet of water in 1990 (table 4), 25 percent from groundwater and 75 percent from surface-water sources. Idaho accounts for 59 percent of the region's water withdrawals for irrigation, and for 51 percent of the region's surface-water withdrawals for irrigation.

[7] Other higher valued crops irrigated in the PNW include seed crops (for grass, vegetable, and flowers), sugar beets, hops, mint for oil, nursery crops, mushrooms, sod, and berries. In 1987, higher valued crops were irrigated on 1.6 million acres in the PNW (U.S. Department of Commerce, 1989).

Table 3--Water withdrawals by water-use category, as a percent of total withdrawals by water source for the Pacific Northwest, 1990[1]

State/region	Municipal[2]	Industrial[3]	Livestock	Irrigation Surface water	Irrigation Groundwater	Total
			Percent			
For total water withdrawals:						
Idaho	1.35	1.07	2.85	61.13	33.60	94.73
Oregon	14.77	3.57	<1	74.71	6.68	81.39
Washington	12.66	11.01	<1	66.45	9.49	75.94
Pacific Northwest	6.98	3.91	1.69	65.48	22.00	87.48
For groundwater withdrawals:						
Idaho	3.12	2.33	7.38		87.22	
Oregon	22.07	4.17	<1		73.40	
Washington	38.96	7.62	1.52		52.00	
Pacific Northwest	9.90	3.70	5.97		80.93	
For surface-water withdrawals:						
Idaho	<1	<1		99.50		
Oregon	14.06	3.53	<1	82.24		
Washington	6.80	11.76	<1	81.28		
Pacific Northwest	5.88	4.05	<1	89.98		

[1]Hydropower water demands are not indicated here because hydropower water-use remains instream.
[2]Includes water withdrawals for public supply, domestic, and commercial purposes.
[3]Includes water withdrawals for industrial, mining, and thermo-electric purposes.
<1 = less than 1 percent.
Source: Solley, Wayne B., Robert R. Pierce, and Howard A. Perlman. *Estimated Use of Water in the United States in 1990.* U.S. Dept. Interior, U.S. Geological Survey, Circular 1081, 1993. (Shares were computed using water withdrawal estimates from tables 4, 6, 8, and 16.)

Agriculture is the likely principal source of water for alternative uses, particularly for large environmental requirements. Furthermore, given agriculture's economic trends, minimal conserved water supplies can be expected in the absence of water policy changes (Schaible, Kim, and Whittlesey, 1991).

Finally, irrigated agriculture in the Pacific Northwest depends heavily upon stored-water reserves from publicly financed BoR water projects. The BoR supplies approximately 75 percent of the surface water used by agriculture in the Pacific Northwest (table 5), irrigating approximately 2.74 million acres in 1990 (U.S. Department of the Interior, 1992c). The largest share of BoR water, 60 percent, irrigates cropland and pastureland in Idaho, accounting for 56 percent of BoR-irrigated acres. Nearly 50 percent of agricultural water use in Idaho is BoR-supplied water.

BoR contract water prices are generally less than full-cost equivalent prices and market marginal opportunity values for water.[8] Contract prices are believed a source of inefficiency in publicly supplied agricultural water use (Ellis and DuMars, 1978; Saliba and Bush, 1987; Wahl, 1989; McKinnon, 1986). Contract prices for BoR-supplied water to agriculture in 1990 averaged $5.36 per acre for the region, while full-cost equivalent prices averaged $30.56 per acre.[9]

Policy Analysis Framework

Estimating water conservation and production impacts for a regional agricultural sector under alternative

[8] BoR contract prices reflect repayment, and operation and maintenance costs, while full-cost equivalent water prices reflect full-cost recovery of the investment in agriculture's share of publicly supplied water. BoR interprets both concepts as defined in the Reclamation Reform Act of 1982 when computing irrigation project-level estimates.

[9] Weighted-average BoR contract water prices vary across the Pacific Northwest: $7.40, $2.64, and $4.73 per acre for Washington, Oregon, and Idaho. Full-cost equivalent prices also vary from $76.70, $20.06, and $9.68 per acre for Washington, Oregon, and Idaho. Contract and full-cost water prices used here are weighted averages for 1990, computed from BoR project estimates (unpublished) received from the Bureau of Reclamation, Denver, CO. Project acres irrigated for 1990 were used to weight BoR estimates (U.S. Department of the Interior, 1992c).

Table 4--Water withdrawals for irrigation by water source in the Pacific Northwest, 1990[1]

State/region	Total	Ground-water	Surface water
		Million acre-feet	
Idaho	20.9	7.4	13.5
Oregon	7.7	.6	7.1
Washington	6.7	.8	5.9
Pacific Northwest	35.4	8.9	26.5

[1]These estimates reflect water quantities at the point of diversion. They do not reflect onfarm water use, that is, water at the farm gate.
Source: Same as table 3.

water policy options requires a flexible modeling framework. This framework should reflect the institutional environment of agricultural land and water resources, identify output-specific production technologies, allow for crop and input substitutions, and recognize hydrologic (streamflow) interactions among modeling subareas. Water policy options in this report are analyzed using an aggregate, multioutput production model of irrigated and dryland crop production. This modeling framework is an accepted approach for agriculture when certain inputs are fixed, that is, restricted in the near term because of economic, financial, institutional, and/or other physical characteristics (Chambers and Just, 1989; Shumway, 1983; Just, Zilberman, and Hochman, 1983; Moore and Negri, 1992).

Land and water resources for agricultural producers are allocatable fixed inputs. As such, they are quantity-rationed and not price-rationed. For a variable input, price explains producer decisions; however, when an input is fixed, its quantity restriction explains producer decisions (Shumway, Pope, and Nash, 1984; Moore and Negri, 1992; Moore and Dinar, 1992).

For surface water, producers hold rights to specific quantities acquired through State-administered, quantity-based permits according to the prior appropriation doctrine (Moore, 1991; Sax and Abrams, 1986). Legal procedures, legislative policies, and administrative rules further impede voluntary transfers. Furthermore, Federal reclamation law and BoR administrative practices impede market transfers by confining BoR water use to the service area of the original irrigation district (Burness and Quirk, 1980; Ellis and DuMars, 1978; Wahl, 1989). Groundwater supplies, also administered by State law, are constrained at the farm level by irrigation infrastructure, such as existing capacity of onfarm wells and distribution systems.

Farm-level cropland in the intermediate term is also a fixed and allocatable resource (Lopez, 1980; Weaver, 1983; Just, Zilberman, and Hochman, 1983; Shumway, Pope, and Nash, 1984). For irrigated land, a marginal increase in developed acreage is quite expensive. Thus, institutional and farm-level rigidities allow both water and land to be treated as fixed and allocatable inputs, rather than as traditional variable inputs, in production decisions.

Table 5--Onfarm agricultural water use by water source in the Pacific Northwest, 1990

State/region	Total agricultural water use	Groundwater withdrawals[1]	Farmgate equivalent estimates of agricultural surface-water use[2]	BoR water delivered to farms[3]
		Million acre-feet		
Idaho	16.5	7.4	9.1	8.2
Oregon	5.6	.6	4.9	1.5
Washington	4.9	.8	4.0	3.7
Pacific Northwest	27.0	8.9	18.1	13.5

[1]These numbers were acquired from Solley, Pierce, and Perlman, U.S. Geological Survey, Circular 1081, 1993.
[2]These estimates were calculated by applying conveyance loss coefficients to surface-water withdrawal estimates provided by Solley, Pierce, and Perlman, U.S. Geological Survey, Circular 1081, 1993. State average conveyance loss coefficients (32.4, 30.3, and 31.6 percent for Idaho, Oregon, and Washington, respectively) were calculated using BoR project data for the Pacific Northwest for 1979-88.
[3]Source: U.S. Department of Interior. *1990 Summary Statistics: Water, Land, and Related Data*. Bureau of Reclamation, Denver CO, 1992.

The modeling framework is a normalized, restricted-equilibrium, primal-dual optimization approach designed to reflect existing agricultural technology.[10] Producers are assumed to allocate resources according to competitive equilibrium criteria. Resource allocations then, are at their optimal longrun equilibrium levels, although conditional on fixed and allocatable land and water resources. The modeling framework follows Lau's (1976) multistage, multioutput, normalized, profit-maximization procedure, and is consistent with the static, longrun, restricted-equilibrium model adopted by Squires (1987). (See box, "A Multistage Production Modeling Framework," p. 9.)

The Western Agricultural Water Analysis (WAWA) Model

The WAWA model, a quadratic primal-dual optimization specification, is used to evaluate selected water policies for this report (Schaible, 1993). WAWA is an interregional, aggregate, multioutput production model defined for 61 modeling subareas (MSA's) in the 17 Western States. This analysis focuses on 11 MSA's in the PNW (fig. 1).[11]

WAWA's unique water policy character benefits this analysis. Land and water resources are identified by MSA for up to nine field crops, separately for irrigated and dryland production. Irrigated land and water resources are further disaggregated into irrigated production with water supplied by the BoR and with water supplied by private sources. Privately supplied water includes onfarm and off-farm surface water, and ground water. Irrigated and dryland field-crop production varies by MSA, but could include crops for alfalfa hay, corn for grain, dry beans, other hay (other than alfalfa), potatoes, sugar beets, small grains (barley, oats, and rye), silage, and wheat (see "Data Sources," p. 28).

The WAWA model recognizes that for some MSA's, water policy consequences may be influenced by interregional surface-water interaction. For example, water conservation in the upper Snake River could enhance fish and wildlife habitat in the lower Snake and Columbia River systems, and provide additional water for agriculture downstream. MSA-level surface-water linkages allow the model to mirror aggregate hydrologic relationships, important for effective interregional water policy analysis. These linkages account for diversion system conveyance losses and natural streamflow losses.

Modeling interregional surface-flow interactions complicates the model's constraint structure, but provides an important interregional water policy link. The model traces observed-equilibrium, diversion-equivalent, surface-water quantities for an MSA's endogenously modeled crop production.[12] Upstream conserved-water supply is assumed to be available for instream uses in downstream MSA's, unless such supplies are institutionally allocated (diverted) for some out-of-stream use, including agriculture (a potential policy option).[13] The use of conserved water, whether for downstream fish and wildlife, hydropower, water quality, recreation, or for diversion demands (urban/agricultural), is a policy question.

Selected Water Policy Options Analyzed for the Pacific Northwest

Water policy options may encompass regulatory and conservation-incentive policies (fig. 2). Regulatory policies would mandate reductions in streamflow diversions and/or restrictions on groundwater withdrawals. Conservation-incentive policies could emphasize institutional reforms, such as alternative water market structures, relaxed restrictions on BoR water allocations and irrigation district economic returns, or defined property rights and procedures to reallocate conserved water.[14] These institutional

[10] For more of the theoretical framework, see Schaible (1993).

[11] MSA's 21 and 24 are included because they are hydrologically connected to the Columbia and Snake River Basins. However, MSA 55 is not included with the PNW model because it is hydrologically connected to the Klamath River Basin in California.

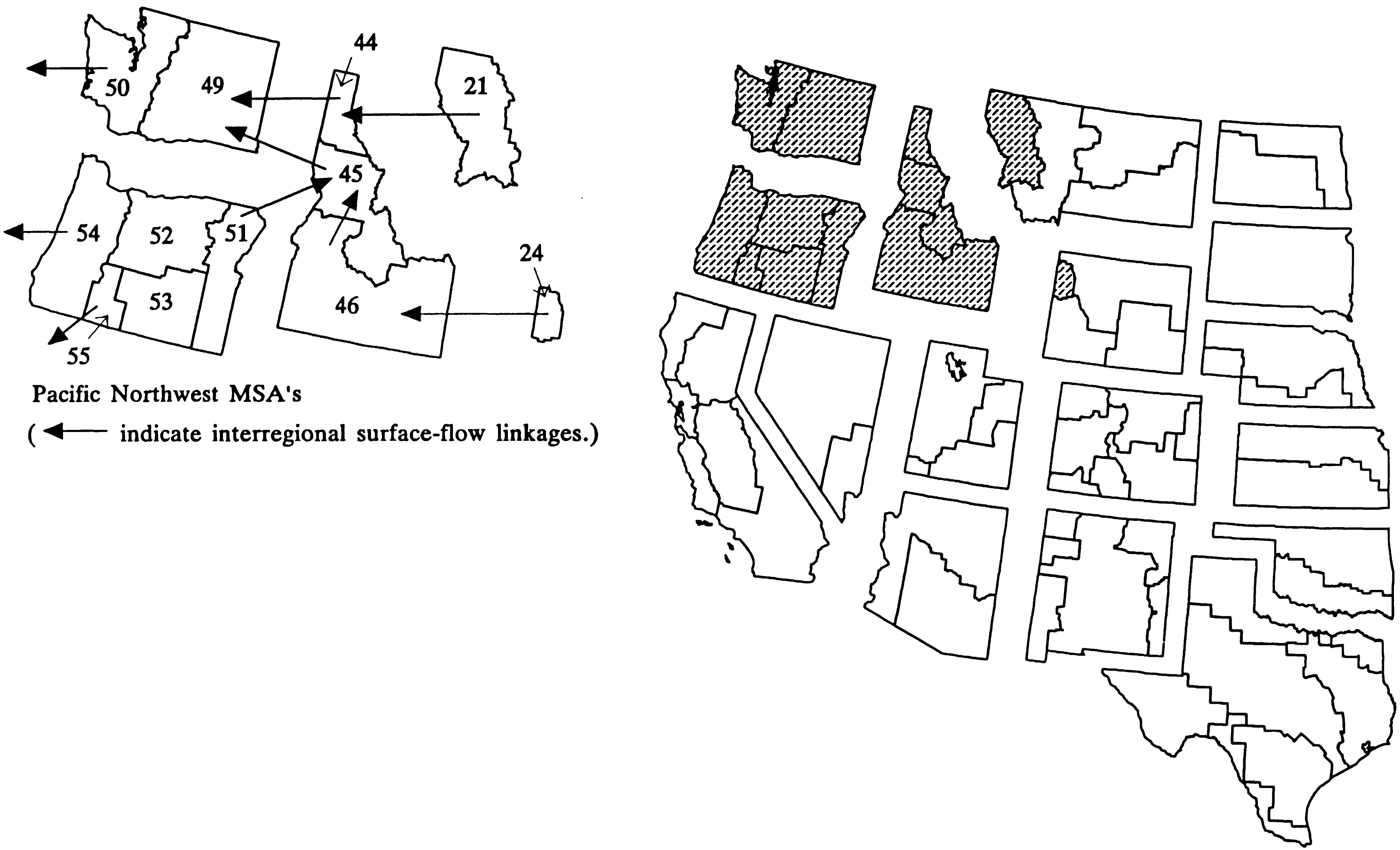
[12] Land and water resource use for nonmodeled crops were subtracted from MSA-level total resource constraints. Crop technologies not modeled include: (1) long-term perennial crops (e.g., orchards, vineyards) for which water use is assumed to be fixed over the life of the established stand, and (2) specialty crops (e.g., vegetables, nursery stock) for which the average value-product of water is assumed to be relatively high.

[13] Diversion-equivalent, conserved agricultural water supplies do not necessarily imply streamflow gains downstream. Tradeoffs with return-flow losses, which would occur during the irrigation season due to conservation, will determine what portion of conserved agricultural water will actually become streamflow gain downstream. Appendix C illustrates this point.

[14] Alternative water market structures are characterized by such factors as determining what water may be marketed, whether the market is permanent or temporary, economic sector participation, and whether the market is administered privately or State-controlled. Reclamation regulation, through appurtenance clauses in State water law, often restricts the use of BoR water to specific parcels of land or project service areas. Administrative regulations generally restrict an irrigation district's economic profits, which limits the implementation of conservation policies and potential economic benefits to existing users. The general lack of legal statutes defining conserved water as a beneficial use promotes fear that rights to conserved water accrue to others. Legal recognition of conserved-water property rights provides producers an incentive to conserve.

Figure 1

Modeling subareas (MSA's) for the Western Agricultural Water Analysis model, defined by State lines and county-line approximations of watershed boundaries



A Multistage Production Modeling Framework

The multioutput, normalized, restricted-equilibrium modeling framework requires a two-stage optimization approach. In stage one, a multioutput, normalized, restricted-profit function model is used to estimate output-specific, temporary or disequilibrium opportunity values of fixed resources at an observed equilibrium. These opportunity values reflect shortrun economies of scope, measured as the difference between shortrun marginal and average costs. Output-specific, disequilibrium opportunity values are recognized by producers as opportunity costs due to allocatable fixed inputs at the observed (restricted) equilibrium. These fixed-resource opportunity values do not equal market fixed-factor rental prices, because the shortrun observed (restricted) equilibrium is unlikely to be at the point where marginal cost equals minimum shortrun and longrun average costs (Lau, 1976; Gorman, 1985; Berndt and Fuss, 1986; Morrison, 1985; Squires, 1987).

Fixed-resource opportunity costs are used to define output-specific, implicit, total economic-cost functions as scalar, total shadow-cost functions. Scalar shadow-cost structures incorporate both total average variable costs at observed equilibrium and a scalar measure of the disequilibrium opportunity costs of fixed inputs. As a behavioral adjustment cost, these scalar opportunity costs reflect the opportunity value of the variable inputs required to be shifted from alternative output choices, that is, costs producers consider to produce output from another acre of a particular crop.

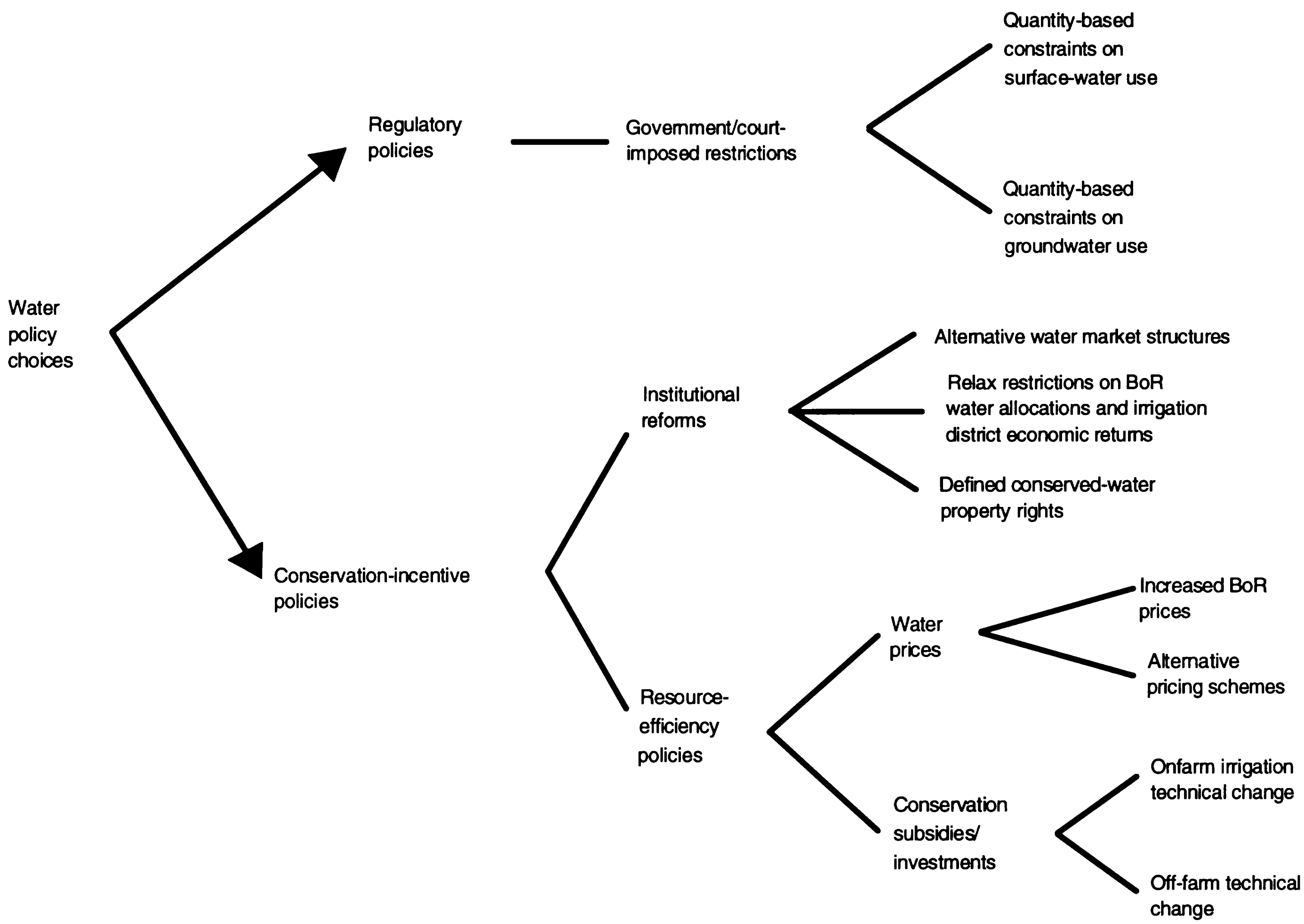
In stage two, the longrun, normalized, restricted-equilibrium model substitutes observed-equilibrium accounting costs for crop-specific, implicit, total economic-cost functions. This primal-dual optimization approach emulates the correspondence between profit maximization (cost minimization) and production technology. In addition, the approach captures producer multioutput production decisions (commodity-specific output supplies and input demands) from the use of variable inputs, subject to the stock of allocatable fixed inputs (Lau, 1976; Berndt and Fuss, 1986; Gorman, 1985; Shumway, Pope, and Nash, 1984; Chambers and Just, 1989; Squires, 1987; Morrison, 1985).

Five assumptions underlie multioutput, agricultural production decisions within this modeling framework: (1) inputs are allocated across crop production activities; (2) production technologies are technically nonjoint, but apparent jointness exists due to allocatable fixed inputs (Shumway, Pope, and Nash, 1984; Chambers and Just, 1989; Squires, 1987); (3) land and water resources are fixed and allocatable; (4) producers account for temporary or disequilibrium opportunity costs of allocatable fixed inputs in making optimal input allocation decisions; and (5) unique substitution possibilities exist, that is, substituting land and water resources to produce more crops that consume less water and less of the water-intensive crops, substituting groundwater-irrigated agriculture (where groundwater irrigation already exists) for surface-water irrigated agriculture, substituting dryland production for irrigated production, and producing less irrigated output.

Assumptions (1) and (2) allow formulation of independent, normalized, restricted-profit functions for each crop production technology. Assumption (3) provides the source of apparent jointness due to fixed allocatable land and water resources. Assumption (4) allows output levels to be endogenous. Assumptions (3), (4), and (5) link agricultural water and land resources as exogenous variables to water conservation policy analysis.

Estimation of reliable scalar economic-cost parameters requires that crop production technology be identified. This model identifies output-specific technologies by normalizing input-output production relationships. Essentially, the normalization process (or scaling procedure) transforms input-output correspondence for a given crop technology into a distance function. The value of the distance function at observed equilibrium reflects an aggregate efficiency value of unity (Gorman, 1968; Hanoch and Rothschild, 1972; Färe and Shephard, 1977). For policy analysis, this efficiency parameter ranges from zero to unity, and allows for analysis of public policy choices encouraging onfarm technical change (for example, public investment (or subsidy) programs promoting adoption of water-conserving irrigation technology). Generating scalar economic-cost functions and the normalization of input-output correspondence enable the restricted-equilibrium model to rationalize the true technology and ensure that optimal solutions are consistent with competitive profit maximization (Varian, 1984; Hanoch and Rothschild, 1972).

Figure 2
Schematic view of alternative water policy choices



changes would affect agricultural water supply for a region through private initiative rather than mandatory supply restrictions. Conservation-incentive policies may also emphasize resource efficiency through increased prices for off-farm purchased (BoR) water, alternative water-pricing rules, or improvements in off-farm water conveyance and in onfarm irrigation technology and water management (irrigation technical change). Investing in (or subsidizing) public water conveyance structures and onfarm, water-conserving irrigation systems reduces water losses and, thus, agricultural water demand.

This report analyzes the following water policy options: reductions in BoR diversions, higher farm-level water prices (purchased-water costs) for BoR surface-water supplies, and both off-farm and onfarm technical change in irrigated agriculture.[15] Also, several policy options combine regulatory and conservation-incentive policies. Alternative policy scenarios were devised for each policy option,

[15] Each of these policy options is evaluated in a partial-equilibrium context, that is, the analysis considers only the direct and substitution effects of the specific policy change, all other factors constant.

Table 6--Observed-equilibrium statistics for modeled field-crop production, Pacific Northwest

Modeling subarea	Surface-water diversion for BoR-supplied water[1]	Conveyance loss coefficients for off-farm surface-water supplies[2]	Weighted average purchased water costs for off-farm surface water[3]
	1,000 acre-feet	*Percent*	*$/acre-foot*
MSA21	28	32.7	5.17
MSA44	2	12.1	7.64
MSA46	2,423	32.6	7.64
MSA49	1,180	31.6	10.68
MSA51	277	34.7	8.35
MSA52	165	33.4	8.35
MSA54	25	15.0	8.35

[1]These numbers reflect diversion-equivalent estimates of the quantity of water diverted at the point of diversion and include only BoR surface-water diversions for the modeled crops by MSA.
[2]Conveyance loss coefficients reflect the percent of BoR diversions that do not reach the farmgate. Such losses account for spills and conveyance system transport losses, both evaporation and percolation losses. Coefficients were calculated using BoR project data, 1979-88.
[3]Calculated using farm-level, purchased-water cost data from the 1984 Farm and Ranch Irrigation Survey (U.S. Department of Commerce, 1986).

reflecting a range of adjustment in policy parameters (fig. 3).

Mandatory reductions of 5-20 percent in BoR surface-water diversions to agriculture were analyzed in four scenarios, A1-A4. Diversion reductions were applied to observed, diversion-equivalent BoR surface-water quantities for modeled crops by MSA (table 6). Reductions in BoR diversions for the PNW range from 205,000 to 820,000 acre-feet per year in scenarios A1-A4.

Water policies encouraging improvements in off-farm and onfarm irrigation technology and water-management systems are analyzed from an aggregate production perspective. Aggregate irrigation technical change refers to a change in MSA-level water-use efficiency for either agricultural resource supply or crop-specific resource use. Efficiency parameters reflect average supply or use environments.[16] Policies designed to promote technical change encourage improved water-resource efficiency and, thus, agricultural water conservation. Off-farm technical change presumes investment that improves surface-water conveyance efficiency. Onfarm technical change presumes investment in water-conserving irrigation technologies and water-management practices that alter crop production systems, such that crop-specific, aggregate, water-use efficiency increases across the study area. Specific investment/subsidy programs are not evaluated, but rather, changes in aggregate, resource-efficiency parameters serve as proxies for their programmatic results.

[16] MSA-level conveyance loss parameters are adjusted for conveyance efficiency of publicly supplied surface water. Output-specific, normalized, water-use efficiency parameters are used to analyze changes in onfarm irrigation application efficiency.

Off-farm technology improvements assume increased conveyance efficiency for BoR-supplied water. Because of losses during conveyance, BoR surface-water diversions for agriculture do not equal BoR-supplied surface water at the farmgate. Distribution systems consist mostly of unlined canals, which often convey water long distances from the point of diversion to the farm. Such systems lose water due to spills, evaporation, and canal seepage. Conveyance losses in the PNW range from 12 to 35 percent of original diversions (table 6). Water conservation impacts were analyzed using five BoR conveyance efficiency scenarios. MSA-level conveyance efficiency parameters were increased from 10 to 50 percent in scenarios B1-B5.

Onfarm technology improvements are analyzed from two perspectives. First, increased irrigation efficiency is assumed to be factor-augmenting (water-saving), with crop-specific yields assumed constant. Second, onfarm technology improvements are analyzed assuming both increased irrigation efficiency and enhanced crop yields. Policy scenarios for each perspective were analyzed separately to isolate onfarm efficiency effects. Technical change of this

Figure 3
Policy simulations evaluated for selected water policy options

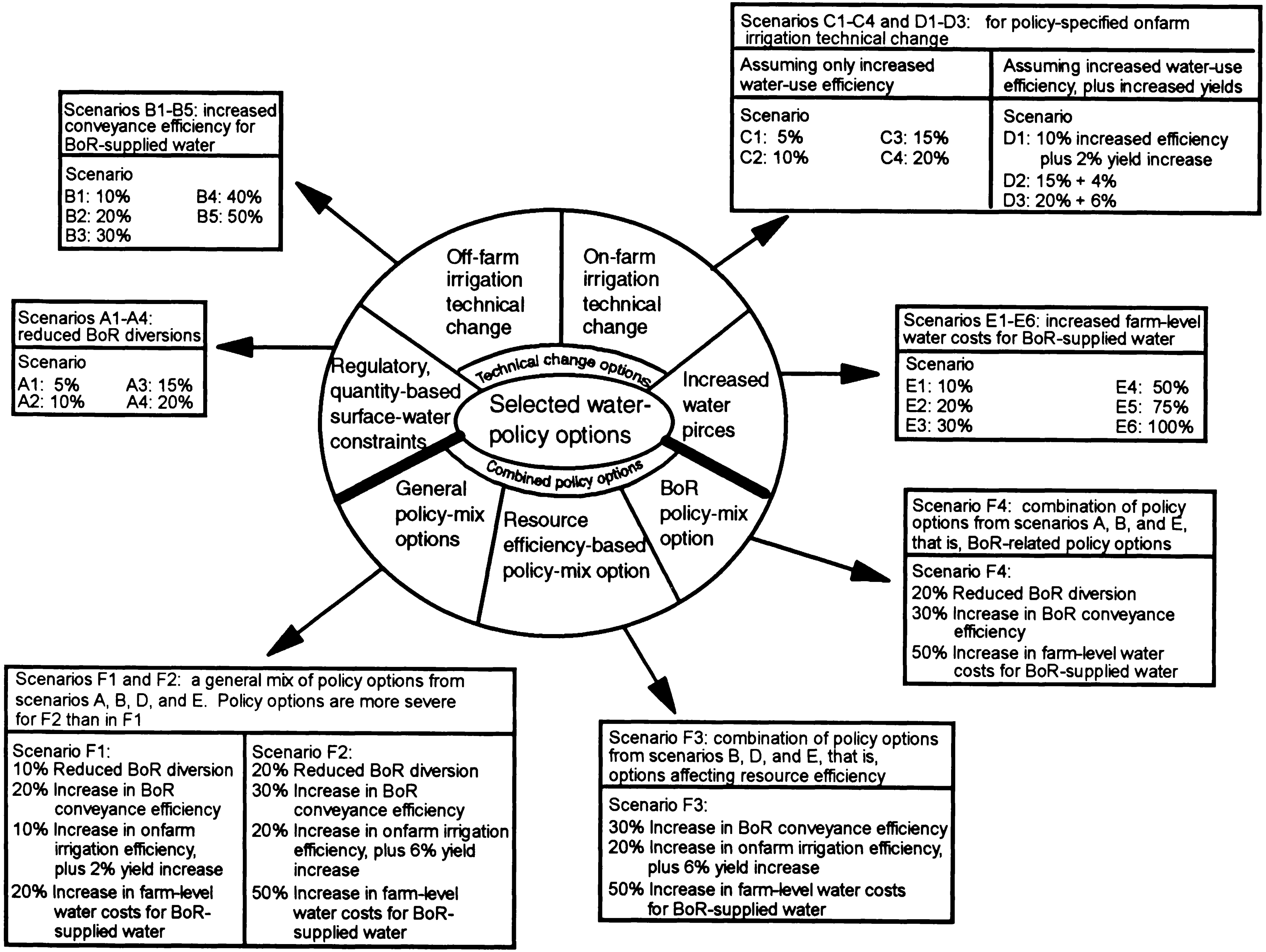


Table 7--Weighted-average irrigation application rates (crop-specific, applied water coefficients) for modeled crops in the Pacific Northwest

State/region	Alfalfa	Corn	Dry beans	Other hay	Potatoes	Sugar-beets	Small grains	Silage	Wheat
					Acre-feet per acre				
Idaho	1.92	2.23	2.17	1.26	2.08	2.69	1.42	1.88	1.48
Oregon	2.17	2.63	NA	2.11	2.36	NA	1.53	1.37	1.67
Washington	2.17	2.48	2.15	1.70	2.53	NA	1.61	2.43	1.68
Pacific Northwest	2.00	2.45	2.16	1.90	2.20	2.69	1.45	1.95	1.57

NA = Not applicable.
Source: From the Western Agricultural Water Analysis Model (Schaible, 1993), based on agricultural water use data from the Farm and Ranch Irrigation Survey, the Census of Agriculture, and BoR water-use data.

type is usually described as progressive technical change, that is, it presumes input-saving, cost-reducing input-output relationships (Chambers, 1988). Such technical change can be, but is not required to be, output-enhancing. However, many water-conserving irrigation technologies that increase uniformity of water distribution and improve the timing of water applications are believed to increase the quality and effectiveness of fixed inputs (Caswell and Zilberman, 1986; Lichtenburg, 1989; Dinar, Letey, and Knapp, 1985; Dinar and Campbell, 1991), and therefore enhance yields.

Onfarm technology and water management improvements alter aggregate crop production technology, shift costs, and entice crop and resource substitution effects due to changes in relative crop profitability. These effects differ across constant-output and yield-enhancing technical change (see appendix A). As producers adopt water-conserving technical improvements, increasing aggregate crop water-use efficiency, water conservation benefits accrue from both irrigation efficiency and substitution effects.

Scenarios C1-C4 assume that aggregate, crop-specific irrigation application efficiencies increase from 5 to 20 percent. Output-enhancing technical change is analyzed in scenarios D1-D3, which assume increases in irrigation application efficiency of 10-20 percent and yield increases of 2-6 percent. Relative efficiency and yield changes are applied across all crop technologies in each MSA. Irrigation technical change is modeled assuming that increased aggregate, irrigation application efficiency reduces weighted-average, crop-specific, applied-water coefficients (table 7).

Resource-efficiency policies that increase farm-level water prices are analyzed by increasing water costs per acre-foot for BoR-supplied water (table 6). Scenarios E1-E6 increase these costs from 10 to 100 percent, by MSA. Higher water costs shift economic-cost functions differently for each irrigated crop, thereby altering relative profitability across crops. Estimated longrun equilibrium effects account for these changes in relative profitability, as well as for differential changes in crop-specific, fixed-resource opportunity costs. These opportunity costs increase (or decrease) with higher water prices because producers substitute production of higher-return crops for lower-return crops.

Individual water policy options will likely impose different burdens on producers and water suppliers, and could alter agricultural production differently among regions in the Pacific Northwest. Combining water policy options may apportion the costs of water conservation more broadly, and possibly enhance the regional agricultural economy.

Combined water policy scenarios are defined for two general policy-mix scenarios (F1, F2), one resource-efficiency policy-mix scenario (F3), and one BoR policy-mix scenario (F4) (fig. 3). Scenarios F1 and F2 include aspects of each of the previous policy options, with policy choices imposed more severely in F2 than in F1. This general policy mix accommodates a policy interest that reflects a greater concern with total conserved-water quantity than with who benefits from reallocation of water supplies. Scenarios F3 and F4 each represent a particular policy focus. Scenario F3 emphasizes greater resource efficiency through off-farm and onfarm irrigation technical change, and through increased water prices for BoR-supplied surface water. Scenario F4 emphasizes a BoR policy focus through reduced BoR diversions and increased conveyance efficiency and water prices for BoR-supplied water.

All policy scenarios assume no institutional restriction on water-source substitution. That is, the analysis did not impose any explicit restriction on the substitution of ground water for BoR surface water (in MSA's where ground water is presently used). Substitution possibilities are restricted, however, to the degree that total water supplies are constrained given an MSA's irrigation infrastructure capacity.

The policy options and scenarios analyzed in this report are not meant to encompass all possible water policy choices. They were selected, however, to reflect a broad array of choices from policy alternatives possible within the present economic and resource environment. These selected water policy choices also reflect the present conceptual structure of the Western Agricultural Water Analysis model and available data.

Analysis of Selected Water Policy Options

Analytic results are presented by policy scenario for each of the selected water policy options (tables 8-11, and appendix tables B1-B13). The tables summarize agricultural water conservation; changes in land and water resource allocations across field-crop technologies, water sources, and resource-production categories;[17] and changes in agriculture's aggregate economic returns. Results are summarized for the Pacific Northwest (PNW) region (in aggregate), sometimes by State, and in terms of percentage changes from baseline values for all variables. Agricultural water conservation and changes in aggregate agricultural economic returns are also measured in acre-feet and in dollar units. Results measure changes only for field-crop production in the PNW.

Water conservation and economic returns vary significantly across water policy options and with their degree of implementation (tables 8-11). Many water policy choices conserve significant amounts of agricultural water with minimal detrimental or even positive economic impact on regional agriculture. Changes in resource allocations across crop technologies, production categories, and by State (app. tables B1-B13) provide insight into the resource-efficient allocations of alternative water policies, and the distribution of the conservation burden among producers, water sources, and regions within the PNW. The appropriate water policy choices for the PNW involve political and social value judgments not evaluated in this report. However, this analysis provides information on the conservation efficacy of selected water policy choices.

Water Conservation Impacts

Agricultural water conservation estimates (table 8) account for the effects of technical efficiency, and the effects of both crop and water-source substitution. Water conservation estimates due to increased BoR conveyance efficiency (table 9) represent surface-water quantities that need not be diverted, and do not affect water supplies at the farmgate. Conservation estimates (tables 8-10) do incorporate streamflow gains at the point of diversion from surface-water conservation, but are unlikely to equal streamflow gain downstream. Conserved water quantities generally reduce the downstream return flow associated with both the water delivery and irrigation that occurred prior to the policy change.

The degree to which conserved water from increased irrigation efficiency results in downstream flow gain depends upon the effect of technical change on crop consumptive use and on the quantity of water returned to streamflow through aquifer percolation during the irrigation season. Crop consumptive use may increase, and thereby reduce prior return flows, due to increased uniformity of water distribution across a field. Reduced return flows downstream of irrigation offset streamflow gains at the point of diversion.[18] However, conserved water quantities due to crop substitution and the substituting of ground water for surface water do increase streamflow both at the point of diversion and downstream. Conserved water due to substitution effects is largely a result of reduced aggregate crop consumptive use. Therefore, water conservation estimates for all policy scenarios (tables 8-10) include downstream flow gains.

Downstream flow gain is likely to be largest for policy scenarios involving reduced BoR diversions

[17] Resource-production categories refer to BoR-irrigated, privately irrigated (ground water), and dryland field-crop production alternatives.

[18] Appendix C illustrates streamflow gain and loss effects occurring downstream using a hypothetical example of technical change in onfarm irrigation application efficiency. The illustration varies assumptions about crop consumptive use and return flows during the irrigation season.

and increased purchased-water costs. Streamflow gain due to improved irrigation efficiency could outweigh gain for policies involving reduced BoR diversions or water price increases. The larger the increase in water-use efficiency, the greater the water conservation from crop substitution effects, and therefore, the greater the downstream flow gain. However, assessing the amount of downstream flow gain involves site-specific hydrologic evaluations beyond the scope of this analysis.

Reducing BoR diversions. Water policy that reduces BoR surface-water diversions (for field crops) by 5 and 20 percent (205,000 and 820,000 acre-feet) results in water conservation (at the farmgate) of 155,000 and 619,000 acre-feet (table 8).[19] Agricultural water conservation amounts to 6 percent of field-crop water use in the PNW for a 20-percent reduction in BoR diversions. Irrigation technology was held constant for this policy option; therefore, conservation estimates largely reflect reduced aggregate consumptive use resulting from crop substitution. Consequently, a greater share of conserved water will likely result in downstream flow gains.

Idaho conserves 366,000 acre-feet of agricultural water (of 619,000 acre-feet in the PNW) for a 20-percent diversion reduction. However, the greater relative impact occurs in Washington, where agricultural water use for field crops drops by 8 percent, compared with 7 percent in Idaho and 3.5 percent in Oregon (table 8).

Off-farm technical change. Increasing conveyance efficiency for BoR-supplied water by 10-50 percent conserves 383,000-1,872,000 acre-feet of water for the PNW (table 9). Conveyance conservation estimates range from 9 to 46 percent of BoR diversions (for field crops) for the PNW, with most of the water savings originating in Idaho and Washington. These estimates reflect streamflow gain at the point of diversion. Their contribution to downstream flow during the irrigation season remains uncertain, but is likely smaller than for other policy choices because crop consumptive use is unchanged. However, if conserved water is significant and return flows from conveyance losses are minimal during the irrigation season, then a policy designed to improve conveyance efficiency may result in larger downstream flow gains (during the irrigation season) than would other water policy options.

Constant-output, onfarm technical change. Water-saving irrigation technologies and management that maintain yields promote agricultural water conservation through crop substitution and by reducing applied irrigation per acre.[20] Even assuming uniform relative efficiency improvements across field crops, different profitability effects entice significant production shifts, which result in less aggregate crop consumptive use and greater water conservation than for technical efficiency alone.[21]

Increasing onfarm irrigation efficiency from 5 to 20 percent conserves 377,000-1,817,000 acre-feet of water for the PNW (table 8), or 4-19 percent of water use for field-crop production. Onfarm technical change has a larger relative impact on agricultural water use in Oregon and Washington (20 percent of field-crop water use), even though Idaho (17 percent) accounts for more conserved water. A 20-percent increase in irrigation efficiency generates 892,000 acre-feet of conserved water in Idaho and only 390,000 and 439,000 acre-feet in Oregon and Washington.

Output-enhancing, onfarm technical change. Irrigation improvements that increase both water-use efficiency and per-acre crop yields conserve substantial amounts of water. Output-enhancing technical change that increases irrigation efficiency by 10 and 20 percent, and crop yields by 2 and 6 percent, reduces field-crop water use by 780,000-1,717,000 acre-feet for the PNW (table 8). Conserved water with output-enhancing technical change declines 5-6 percent for the PNW, relative to conservation with irrigation efficiency improvements

[19] The difference between a reduced diversion quantity and the conserved quantity at the farmgate is attributable to conveyance losses not diverted.

[20] This analysis assumes that the aggregate, irrigated-crop production technology does not reflect a deficit irrigation relationship. Deficit irrigation refers to an irrigation production technology where, for any particular irrigation system, producers apply less water than the crop's consumptive-use requirement. This production technology results in reduced crop yield. While some producers may deficit-irrigate a particular crop, this production practice is not representative of aggregate, irrigated-crop production technology. Aggregate, average applied water rates are greater than crop consumptive-use requirements.

[21] Analysis of water conservation from an engineering, irrigation-efficiency perspective (that is, per-acre reduction in applied water), ignores crop substitution effects. A multioutput production framework with an endogenous total economic-cost function captures these effects. The advantage here is that the degree to which agricultural water conservation estimates reflect savings in aggregate crop consumptive-use also illustrates the degree to which water conservation estimates reflect downstream flow gain.

Table 8--Agricultural water conservation for selected water policy scenarios, Pacific Northwest

Policy option/scenario[2]	Net aggregate water conservation for BoR and private water supplies (at the farmgate)[1]				Percentage conservation effects			
	Idaho	Oregon	Washington	Total	Idaho	Oregon	Washington	Total
	1,000 acre-feet				*Percent of field-crop water use*			
Reduced BoR diversions:								
A1: 5%	91	18	45	155	1.8	.9	2.0	1.6
A2: 10%	183	35	90	310	3.6	1.8	4.0	3.1
A3: 15%	274	53	135	465	5.3	2.6	6.1	4.7
A4: 20%	366	70	179	619	7.1	3.5	8.1	6.3
Onfarm technical change (for increased water-use efficiency only):								
C1: 5%	158	91	106	377	3.1	4.5	4.8	3.8
C2: 10%	365	190	217	819	7.1	9.5	9.8	8.3
C3: 15%	628	290	328	1,316	12.2	14.6	14.8	13.4
C4: 20%	892	390	439	1,817	17.4	19.6	19.8	18.5
Onfarm technical change (increased water-use efficiency, plus yield increases):								
D1: 10% + 2%	334	187	213	780	6.5	9.4	9.6	7.9
D2: 15% + 4%	569	284	320	1,243	11.1	14.2	14.4	12.6
D3: 20% + 6%	812	381	428	1,717	15.8	19.1	19.3	17.5
Purchased-water price increases:								
E1: 10%	n	n	n	n	n	n	n	n
E2: 20%	n	n	n	n	n	n	n	n
E3: 30%	n	n	1	1	n	n	n	n
E4: 50%	n	n	19	19	n	n	.9	.2
E5: 75%	n	n	102	102	n	n	4.6	1.0
E6: 100%	n	n	138	138	n	n	6.3	1.4
Combined water-policy alternatives:								
General policy-mix options[3]--								
F1	474	188	215	922	9.2	9.4	9.7	9.4
F2	891	382	431	1,800	17.4	19.2	19.5	18.3
Resource-efficiency policy-mix option[3]--								
F3	834	382	431	1,743	16.3	19.2	19.5	17.7
BoR policy-mix option[3]--								
F4	336	64	164	568	6.5	3.2	7.4	5.8

n = no net aggregate water conservation impact, meaning ground water was substituted for reduced surface-water use.

[1]These estimates include conservation due to onfarm irrigation efficiency, and both crop and water-source substitution effects. These water conservation numbers are not necessarily equivalent to downstream flow gain. These conserved water estimates would need to be balanced against reductions in prior return flows due to a policy shock. This issue, however, is best addressed by hydrologists. (For further discussion, see appendix C.)

[2]For each policy scenario, percents indicate the policy shock in terms of a percent change in baseline values. For example, for scenario D1 the term (10%+ 2%) refers to a 10-percent increase in aggregate water-use efficiency across crops, with yields increasing by 2 percent. For a description of policy scenarios, see fig. 3.

[3]See description, fig. 3.

Table 9--Water conservation due to increased efficiency in conveyance of BoR-supplied water by State and the Pacific Northwest[1]

Conveyance efficiency scenarios for BoR-supplied water	Idaho	Oregon	Washington	Pacific Northwest
		1,000 acre-feet		
B1 - 10%[2]	193	27	155	383
B2 - 20%	380	54	307	755
B3 - 30%	566	81	458	1,127
B4 - 40%	753	108	609	1,500
B5 - 50%	939	135	760	1,872

[1]Results for policy scenarios involving BoR conveyance efficiency were isolated here, because increased conveyance efficiency does not affect agricultural water supply at the farmgate, and therefore does not affect agricultural output or resource distribution across outputs.
[2]For each scenario, percentages refer to the percent decrease in conveyance loss coefficients across MSA's.

only (yields constant). Technical change that increases crop yields alters relative crop profitability and crop substitution effects, which produce less crop consumptive-use savings than does technical change alone. Therefore, output-enhancing technical change may have less impact on both water conservation and downstream flow than does technical change alone.

Investment (or subsidy) policies designed to encourage irrigation efficiency will conserve more water with technical change emphasizing reductions in irrigation waste rather than increased output. This type of technical change shifts technology from flood irrigation and unmanaged high-pressure sprinkler systems to more management-intensive systems, including surge-flow and cablegation gravity systems, low-pressure sprinkler systems, and systems using soil-moisture sensing and irrigation-scheduling practices. These technologies are designed to apply water more closely approximating crop consumptive-use requirements, and to allow the producer more flexibility in timing irrigations.

Increased water prices. Water policy that increases farm-level water prices for BoR-supplied water will not produce net conserved water of any appreciable magnitude (table 8). Increasing water prices as much as 20 percent has no impact on net aggregate water conservation. Increasing water prices 100 percent results in only 138,000 acre-feet of net aggregate water conservation in the PNW, all of which occurs in Washington.

Net water conservation estimates are net of any increase in groundwater (private) use. Producers respond to increased purchased-water costs by substituting crops and by substituting ground water for publicly supplied surface water, such that net aggregate conservation effects are zero or minimal. Water price increases of 10 and 100 percent (table 10) do conserve 116,000-959,000 acre-feet (at the farmgate) of BoR surface water. The largest share of these water savings occurs in Idaho.

Relative conservation effects of water price increases illustrate the unresponsive (inelastic) demand for BoR-supplied water when ground water is available. For a 10-percent increase in farm-level purchased-water costs, agricultural demand for BoR water declines by only 5, 1, 3, and 4 percent for Idaho, Oregon, Washington, and the PNW (table 10). Water price increases of 100 percent reduce demand by 31 percent for the PNW, with the major responses occurring in Washington and Idaho.

Conservation estimates of BoR-supplied water with water price increases are exclusively due to substitution effects and, therefore, reflect changes in crop consumptive use. Because onfarm irrigation technology is held constant, and ground water substitutes for BoR-supplied water, return flows from irrigation are unaffected. Reduced BoR diversions due to increased water costs will contribute significantly to streamflow gain at the point of diversion and downstream.

Combined water policy options. Combining water policy choices within a policy reform package has different water conservation impacts, depending upon the degree of implementation and the focus of the overall policy. For example, the more severe policy-mix option, F2, generates 1.8 million acre-feet of conserved water for the PNW, compared with 922,000 acre-feet for policy-mix option F1 (table 8).

Table 10--Conservation of onfarm BoR-supplied water due to increased farm-level water costs for BoR-supplied surface water in the Pacific Northwest[1]

Purchased-water price scenario	Conservation of BoR-supplied water (at the farmgate) due to crop substitution effects				Percent of BoR-supplied water (at the farmgate) for field-crop production			
	Idaho	Oregon	Washington	Total	Idaho	Oregon	Washington	Total
	1,000 acre-feet				*Percent*			
E1 - 10%[2]	86	5	25	116	4.7	1.3	2.7	3.7
E2 - 20%	176	9	49	234	9.6	2.6	5.4	7.6
E3 - 30%	265	15	74	354	14.5	3.9	8.2	11.5
E4 - 50%	420	23	136	579	23.0	6.5	15.1	18.8
E5 - 75%	517	34	251	802	28.3	9.7	27.9	26.1
E6 - 100%	612	45	302	959	33.5	13.0	33.6	31.2

[1]Conservation of onfarm BoR-supplied water due to increased water prices was isolated here because producers substitute ground water for publicly supplied surface water for this policy option. This table presents a truer picture of agricultural surface-water conservation for price-based water policy scenarios.
[2]For each purchased-water price scenario, percentages refer to the percent increase in farm-level water cost for BoR-supplied water.

In addition, simultaneously imposing alternative water policy choices results in more significant conservation than with a policy change involving only one policy choice. For example, a policy mix that (1) reduces BoR diversions by 10 percent, (2) enhances BoR conveyance efficiency by 20 percent, (3) increases onfarm irrigation efficiency by 10 percent (including yield increases of 2 percent), and (4) increases farm-level purchased-water costs by 20 percent has a greater aggregate conservation effect (922,000 acre-feet) for the PNW (F1, table 8) than similar singularly imposed policy choices (310,000 acre-feet for A2 (table 8); 755,000 acre-feet for B2 (table 9); 780,000 acre-feet for D1 (table 8); and 234,000 acre-feet for E2 (table 10)). Larger conserved-water quantities and the ability to spread the conservation burden are advantages of combined water policy options. A policy-mix option becomes an important policy instrument, particularly when decisionmakers target specific and significant conservation needs.

A policy-mix option may take a particular policy focus. Net conservation estimates suggest that a water-resource efficiency policy mix would conserve significantly more water (1,743,000 acre-feet) than a BoR policy mix (568,000 acre-feet) for the PNW (table 8). However, net aggregate conservation estimates understate actual conservation for a BoR policy mix since water price increases for publicly supplied water encourage substitution of ground water, and therefore reduce net aggregate conservation. A BoR policy mix will conserve significant BoR water (814,000 acre-feet for the PNW, including 508,000, 76,000, and 230,000 acre-feet for Idaho, Oregon, and Washington). Conserved BoR water accounts for 26 percent of BoR-supplied water for PNW field-crop production (28 percent in Idaho, 22 percent in Oregon, and 26 percent in Washington).

Although water-source substitution for the BoR policy mix increases groundwater use by 4 percent for the PNW, conserved BoR-supplied water reflects streamflow gain at the point of diversion and downstream. Downstream flow increases for a BoR policy mix because conserved-water quantities largely involve water formerly used for crop consumptive requirements. The substitution of ground water for BoR-supplied water also reduces the negative effect on downstream flow gain due to changes in return flows. This water substitution effect shifts the source of return flows (from BoR-supplied surface water to ground water), but changes in the quantity of return flows are probably negligible.

General policy-mix and resource-efficiency policy-mix options reduce both surface-water and groundwater use. The contribution that conserved surface water makes to downstream flow, then, depends upon the effect of onfarm and off-farm efficiency changes on reducing return flows. Even so, the magnitude of the conservation and downstream flow gain could equal or surpass that of a BoR policy-mix option, depending upon the degree of implementation of each policy option.

Agricultural Economic Impacts

Changes in aggregate agricultural economic returns (producer welfare) identify the agricultural economic impacts of alternative water policies (table 11). These policies may alter economic-cost structures for outputs, but will always change economic costs for outputs when fixed resources (land and water) are reallocated across outputs. Economic costs increase as more fixed resources are allocated to a particular output, whereas costs decrease for outputs using fewer fixed resources. Producers reallocate fixed resources under alternative water policies because their previous allocation no longer maximizes their agricultural economic returns. Changes in opportunity costs of fixed resources (economic returns forgone) across outputs induce producers to reallocate fixed resources and to maximize economic returns.

For water policies involving irrigation technical change or increased water prices, economic returns across crops are affected by differing shifts in economic-cost structures. For mandatory restrictions on agricultural water supplies (through reduced BoR diversions), economic costs increase when producers allocate fixed resources to expand production of higher return crops. For all policies, crop-specific economic costs may increase because expanded use of fixed resources means higher opportunity costs of variable inputs that must be shifted from alternative crop production choices.

Water policies analyzed here have minimal impact on aggregate agricultural economic returns for field-crop production. For the PNW, agricultural economic impacts range from a 2-percent decrease with a 100-percent increase in purchased-water prices, to a 13-percent increase with a 20-percent increase in onfarm irrigation efficiency assuming a 6-percent increase in yields (table 11). This suggests that significant flexibility exists in options to change water policy without harming regional field-crop agriculture. Decisionmakers therefore can be relatively indifferent to aggregate agricultural effects in their policy choices. Other policy goals (such as water quality, endangered species protection, and property rights equity) increase in relative importance.

Aggregate agricultural economic returns decline for water policy involving reductions in BoR diversions alone, purchased water price increases alone, or for a BoR policy mix that simultaneously imposes diversion reductions, water price increases, and increased conveyance efficiency. Detrimental economic impacts are minimal, however, because producers substitute crops and water sources, and increase dryland production in response to policy change.

Modest positive agricultural economic impacts are achieved from water policies involving onfarm irrigation technical change. Irrigation technology adoption in the PNW, in the absence of policy-induced incentives, is relatively slow (Schaible, Kim, and Whittlesey, 1991). Modest economic benefits of technical change imply the need for public investment (or subsidies) to entice adoption of water-saving technologies.

A caveat is required, however, when interpreting agricultural economic impacts for policy scenarios involving onfarm irrigation technical change.[22] The longrun equilibrium character of the analytic framework assumes that all costs are variable, and accounts for total economic costs. For some irrigation technologies, per-acre investment costs may increase; for other technologies, costs may decrease. For this analysis, improving onfarm irrigation efficiency is assumed not to change output-specific, aggregate, per-acre producer investment costs. Investment costs of technical change are assumed to be the public cost of acquiring conserved-water quantities for the policy's public reallocation goals (or public good). When investment costs for policy-specified onfarm technical change are fully subsidized, positive economic returns identify the aggregate producer economic incentive to conserve. These returns measure the compensation due producers for the economic opportunity value of the conserved water to agriculture.

Positive economic returns also reflect agriculture's ability to pay for the increased irrigation efficiency, while remaining as well off as before the policy-specified change in technology. Onfarm technical change not fully subsidized, however, shifts policy costs to producers, thereby reducing their incentive to conserve and inhibiting the policy's public goals. The subsidy (or public investment) share, then, reflects the margin by which the public encourages maximum producer conservation and ensures that water conservation needs for public

[22] Policy scenarios for onfarm technical change were analyzed assuming that similar relative irrigation efficiency changes are applied across all irrigated field crops.

Table 11--Agricultural economic impacts for selected water policy scenarios, Pacific Northwest

Policy option/scenario[1]	Change in net agricultural economic returns (producer welfare changes) for field crops: Idaho	Oregon	Washington	Total	Percentage economic effects: Idaho	Oregon	Washington	Total
	$1,000				*Percent of field-crop returns*			
Reduced BoR diversions:								
A1: 5%	-1,233	-164	-163	-1,564	-.2[2]	-.1	p	-.1
A2: 10%	-2,719	-396	-379	-3,504	-.5	-.2	-.1	-.3
A3: 15%	-4,458	-698	-648	-5,820	-.8	-.3	-.1	-.4
A4: 20%	-6,450	-1,070	-969	-8,512	-1.2	-.4	-.2	-.7
Onfarm technical change (for increased water-use efficiency only)[3]:								
C1: 5%	5,815	1,394	2,090	9,546	1.1	.6	.4	.7
C2: 10%	10,046	2,541	3,798	16,858	1.9	1.1	.7	1.3
C3: 15%	13,344	3,493	5,161	22,680	2.5	1.5	1.0	1.8
C4: 20%	15,850	4,256	6,187	27,170	3.0	1.8	1.2	2.1
Onfarm technical change (increased water-use efficiency, plus yield increases)[3]:								
D1: 10% + 2%	37,856	9,697	15,387	64,294	7.2	4.1	3.0	5.0
D2: 15% + 4%	69,352	17,859	28,420	118,078	13.2	7.5	5.5	9.2
D3: 20% + 6%	100,384	25,882	41,184	170,977	19.0	10.9	8.0	13.3
Purchased-water price increases:								
E1: 10%	-1,363	-291	-944	-2,608	-.3	-.1	-.2	-.2
E2: 20%	-2,658	-578	-1,862	-5,119	-.5	-.2	-.4	-.4
E3: 30%	-3,884	-861	-2,754	-7,529	-.7	-.4	-.5	-.6
E4: 50%	-6,137	-1,415	-4,453	-12,055	-1.2	-.6	-.9	-.9
E5: 75%	-8,730	-2,087	-6,330	-17,219	-1.7	-.9	-1.2	-1.3
E6: 100%	-11,137	-2,736	-7,957	-21,922	-2.1	-1.1	-1.5	-1.7
Combined water policy alternatives[3]:								
General policy-mix options--								
F1	34,467	9,165	13,683	58,649	6.5	3.9	2.7	4.5
F2	94,735	24,697	37,468	160,386	18.0	10.4	7.3	12.4
Resource-efficiency policy-mix option--								
F3	94,979	24,704	37,468	160,636	18.0	10.4	7.3	12.5
BoR policy-mix option--								
F4	-11,339	-2,197	-4,673	-18,273	-2.1	-.9	-.9	-1.4

p = less than -.1 of 1 percent.

[1]For each policy scenario, percents indicate the policy shock in terms of a percent change in baseline values. For example, for scenario D1 the term (10% +2%) refers to a 10-percent increase in aggregate water-use efficiency across crops, with yields increasing by 2 percent. For a description of policy scenarios, see fig. 3.

[2]The number (-.2) is interpreted as negative 0.2 of 1 percent, meaning that net agricultural economic returns for policy alternative A1 for Idaho declined by 0.2 of 1 percent.

[3]For policy options involving improvements in onfarm irrigation technology and water-management systems (irrigation technical change), investment costs of technical change are assumed to be fully subsidized. Such costs are recognized here as the public cost of acquiring the conserved-water quantities for the policy's public reallocation goals. Positive economic returns reflect the opportunity value of the conserved water to agriculture. (For further explanation, see "Agricultural Economic Impacts," p. 19.)

reallocation goals are a shared public burden.[23] Investment costs for onfarm technical change greater than aggregate producers' ability to pay reflect a public cost for conserved water larger than the opportunity cost of that water in agriculture. Alternatively, public investment costs greater than aggregate producers' ability to pay measure the minimal public (existence) value for the public good(s) derived from the conserved water.

For a policy that reduces BoR diversions, negative economic impacts likely extend beyond field-crop production to the livestock sector, which would suffer from reduced alfalfa production. For example, when BoR diversions are reduced by 20 percent, total irrigated alfalfa acres are reduced by 19 percent and dryland alfalfa acres increase by 23 percent. This shift to dryland acreage is insufficient to compensate for reduced irrigated alfalfa production because of lower alfalfa yields on dryland and fewer total alfalfa acres. Dryland alfalfa production increases 22 percent, but total alfalfa production still declines by 16 percent. Lower alfalfa production of this magnitude is likely to increase regional alfalfa prices and reduce economic returns for the livestock sector.[24] To reduce these negative impacts, a BoR policy focus must also emphasize onfarm irrigation technical change. Increased irrigation efficiency alters relative crop profitability and crop substitution effects, such that alfalfa production increases rather than decreases.

Resource Allocation Impacts

Alternative water policies will significantly affect water and land allocations within PNW agriculture. For some water policy options, producers substitute ground water for surface water, in addition to reallocating land and water across crop outputs. For other policy options, producers reduce both surface-water and groundwater use, while substituting dryland production for irrigated production.

Water Resource Allocations

Reduced BoR diversions. Reducing BoR surface-water diversions (scenarios A1-A4) decreases total water use for most field crops across the PNW. Alfalfa's water use declines most, 5-19 percent for diversion reductions of 5-20 percent. Total water use would increase (2-5 percent) only for small grains (oats, barley, and rye) due to crop substitution effects. PNW water use drops 2-6 percent, net of groundwater substitutions across crops, but with no change in total groundwater use (app. table B1).

Producers significantly reduce BoR surface-water use for all field crops, and increase groundwater use significantly for small grains by reducing groundwater use for other field crops (app. tables B2 and B3). Reduced surface-water use for alfalfa, small grains, and sugar beets accounts for most water conservation with reduced BoR diversions. For a 20-percent reduction in BoR diversions in the PNW (scenario A4), surface-water use declines by 44, 39, and 15 percent for alfalfa, small grains, and sugar beets, while ground water used for small grain production increases by 21 percent.

Imposing reductions in BoR diversions uniformly across the PNW results in similar regional impacts for field-crop water use, with Idaho and Washington incurring only slightly greater impacts (app. table B4). Total field-crop water use declines by 7 percent in Idaho, 3.5 percent in Oregon, and 8 percent in Washington for a 20-percent reduction in BoR diversions. The reduction in total surface-water use and the significant substitution of ground water for surface water across crops confirms that much of the conserved water (indicated by scenario A4 in table 8) reflects former crop consumptive use. Reductions in BoR diversions, therefore, likely contribute significantly to downstream flow.

Onfarm irrigation technical change. Technology and water management improvements that increase irrigation efficiency by 20 percent induce PNW producers to reduce BoR surface-water use by 20 percent, groundwater use by 18 percent, and total water use by 19 percent. If the irrigation technical change is output-enhancing, decreases in water use are slightly less (scenarios C4 and D3, app. table B1).

Increases in irrigation efficiency of 5-15 percent reduce total water use for all PNW field crops except alfalfa and sugar beets (scenarios C1-C2, app. table B1). Producers respond to relative changes in economic returns by substituting alfalfa and sugar beet production for small grains (barley, oats, and

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[23] Shifting total investment costs for a policy-specified change in aggregate, onfarm irrigation efficiency to producers reflects a publicly imposed "best-management-practice" or regulatory approach to technology-based water policy reform. Aggregate positive economic returns and conserved agricultural water reported here are reduced, but, more important, producers are not compensated for the full opportunity value of the conserved water to agriculture.

[24] Increased alfalfa prices would likely have an induced-production effect, both for alfalfa and livestock production, to ensure adequate regional alfalfa hay supplies. This effect is not measured here, but aggregate economic returns for the livestock sector would be expected to decline.

rye) and wheat (scenarios C1-C2, app. tables B6 and B7). For larger increases (20 percent) in irrigation efficiency alone, the aggregate efficiency effect outweighs the output substitution effect and reduces total water use across all field crops. The output substitution effect is greater, however, when irrigation technical change is output-enhancing, resulting in increased total water use for alfalfa and sugar beet production (scenarios D1-D3, app. table B1).

Crop-specific impacts by water source are similar under all technical change scenarios, except that BoR water use for small grains declines more significantly than does groundwater use for small grains (app. tables B2 and B3). The substitution effects of increased alfalfa and sugar beet production are also slightly larger for groundwater-irrigated production than for production using BoR-supplied water. However, small grain production, whether irrigated with BoR surface water or ground water, incurs the largest water-use impacts due to technical change policy. Reductions in BoR-supplied water use for small grain production range from 66 percent with a 20-percent increase in water-use efficiency to 83 percent when the technical change is output enhancing (scenarios C4 and D3, app. table B2). Under similar technical change assumptions, reductions in groundwater use for small grains range from 39 percent to 50 percent (scenarios C4 and D3, app. table B3).

Irrigation technical change promotes slightly larger relative declines in BoR water use in Idaho than in Oregon or Washington (app. table B4). Declines in groundwater use, however, are slightly less in Idaho, where increased irrigation efficiency results in greater substitution of groundwater-irrigated production (app. table B10). These substitution effects imply a larger potential for benefits from a gain in downstream flow in Idaho during the irrigation season.

Increased water prices. As farm-level BoR water costs are increased (by 10 to 100 percent, scenarios E1-E6, app. table B1), PNW farmers substitute ground water for BoR water. A 100-percent increase in farm-level costs for publicly supplied water has minimal effect (-1.4 percent) on total water use, even though BoR water use declines by 31 percent across the PNW.

Water-source substitutions with increased water prices are not equal across crops. Total water use declines for dry beans, sugar beets, and small grains, because surface-water use for these crops declines more than the increase in groundwater use. Total water use for alfalfa, corn, other hay, and wheat crops generally increase, because groundwater use more than offsets the decline in surface-water use. Only with significant water price increases does the reduction in surface-water use exceed groundwater substitution for all field crops (scenarios E5-E6, app. table B1).

Increasing water prices decreases demand for BoR surface water across all field crops for the PNW (app. table B2). Demand drops most in alfalfa and small grain production: 6-66 percent for alfalfa and 15-79 percent for small grains, with water price increases of 10 and 100 percent. Similarly, ground water substitutes for surface water for all field crops (app. table B3), with larger groundwater impacts in alfalfa and small grain production.

Water-source substitutions with increased water prices are significant in both Idaho and Washington (app. table B4). These substitutions balance out across the PNW for total water use for water price increases of 50 percent or more, except in Washington. Total water use in Washington decreases because producers substitute less ground water than is lost in surface water.

Combined water policy options. For combined policy options, reallocation of agricultural water resources generally reduces both BoR surface-water use and groundwater use, thereby reducing total water demand for PNW agriculture (scenarios F1-F4, app. table B1). Efficiency effects and water-source and crop substitution effects reduce total water use by 9 and 18 percent for the two general policy-mix options, F1 and F2; by 18 percent for the efficiency-oriented policy-mix option, F3; and by 6 percent for the BoR policy-mix option, F4. The impact on total water use is smaller for the BoR policy-mix option because net groundwater substitutions are positive.

Policy-mix options F1-F4 all impose a larger relative impact on agriculture's use of surface water than ground water (app. table B1). For options F1-F3, water-source substitution reduces groundwater impacts by balancing groundwater substitution against the efficiency effect of improved technology and water management in groundwater-irrigated agriculture (app. tables B5 and B10). For the BoR policy-mix option, which does not consider irrigation technical change, the relatively small increase (4 percent) in groundwater use is due exclusively to groundwater substitution (scenario F4, app. table B1). Demand for BoR water declines 26 percent for the PNW.

Crop-specific water allocation impacts for policy-mix options reveal that BoR water use declines for most crops (app. table B2). Output substitution due to increased irrigation efficiency allocates modest increases in BoR water use for sugar beets. Reductions in surface-water use affect alfalfa and small grain production the most. Policy-mix options emphasizing significant improvements in irrigation technology and water management reduce groundwater use for most field crop production, but significantly increase groundwater use for sugar beet production (scenarios F2 and F3, app. table B3). For a BoR policy-mix option (scenario F4), however, groundwater substitutions are greatest in small grain production.

Policy-mix options do not promote serious differential allocation impacts across PNW States, although impacts do shift across water sources with shifts in policy focus (app. table B4). A BoR policy mix (F4) significantly reduces BoR surface-water use, while encouraging small increases in groundwater use across the PNW. A resource-efficiency policy mix significantly reduces BoR surface-water use and groundwater use, resulting in significant reductions in total water use across the PNW. These policy-mix options imply that overall water policy focus is critical, depending upon policy goals. A policy focus on streamflow enhancement or water quality significantly affects producer water-resource allocations. A resource-efficiency policy mix that conserves ground water also enhances groundwater quality goals. Different regional, water-resource allocation impacts will be a function of specific, regional water policy. A different policy focus is required across States to respond to different policy goals.

Land Resource Allocations

Reducing BoR diversions. Policy that reduces BoR surface-water diversions causes producers to shift BoR-irrigated acreage to groundwater-irrigated and nonirrigated (dryland) crop production, and to reduce total irrigated acreage (scenarios A1-A4, app. table B5). For a 20-percent reduction in BoR diversions, assuming irrigation technology remains constant, BoR-irrigated acres decline by 20 percent, groundwater-irrigated acres increase by 1 percent, total irrigated acres decline by 5 percent, and acres devoted to dryland field-crop production increase by 4 percent. Irrigated acres decline most for alfalfa and sugar beet production, with smaller declines in total irrigated acres for most other field crops. Producers increase total irrigated small grain acres by shifting the water source from BoR surface water to ground water (app. tables B6 and B7). Groundwater supply is available for additional small grain production because producers reduce groundwater-irrigated acreage for most other field crops (app. table B7). Acres formerly irrigated with BoR surface water and not shifted to groundwater irrigation return to dryland production. For a 20-percent reduction in BoR diversions, PNW producers increase dryland alfalfa acres by 23 percent, with modest increases in dryland acres for other hay, small grain, and wheat production (app. table B8). Diversion reductions, however, cause only modest total acreage shifts from alfalfa, corn, dry bean, and sugar beet production to small grain and wheat production (app. table B9).

Reducing BoR diversions promotes similar aggregate acreage shifts across States, except that dryland field-crop acres in Idaho increase slightly more (app. table B10). With a 20-percent reduction in BoR diversions, dryland field-crop acres increase 9.5 percent in Idaho and 2 percent in Oregon and Washington.

Crop-specific acreage shifts, however, differ across States for a particular resource production category. For Idaho, the principal acreage reductions occur in BoR-irrigated alfalfa and small grain production, with modest decreases in sugar beet acres (app. table B11). For Oregon, the principal acreage reductions occur in BoR-irrigated alfalfa, small grain, and corn production. For Washington, the largest reductions occur in alfalfa acres. The substitution of groundwater-irrigated small grain acres occurs primarily in Idaho, with only modest increases in Oregon (app. table B12). Dryland acreage substitutions are significant for dryland alfalfa in Idaho, with small relative changes elsewhere in the PNW (app. table B13).

Onfarm irrigation technical change. A policy promoting increased irrigation water-use efficiency throughout the PNW (with or without yield increases) causes small reductions in total BoR-irrigated acres, and even smaller relative increases in total groundwater-irrigated acres (scenarios C1-C4 and D1-D3, app. table B5). Total irrigated and total dryland acreage allocations are unaffected. For both BoR- and groundwater-irrigated production, reductions in small grain acreage provide the land resources to increase acreage for most other field crops (app. tables B6 and B7). Alfalfa and sugar beet acres increase the most. The impact on BoR-irrigated small grain acreage is larger than on groundwater-irrigated small grain acreage. Groundwater-irrigated alfalfa increases more than BoR-irrigated alfalfa, while increases for sugar beets are similar for both production categories. If the irrigation technical change is output-enhancing, relative crop substitutions are larger than with increased irrigation efficiency alone.

Substitution effects of irrigation technical change reduce total small grain acreage, which declines 13 percent with a 20-percent increase in irrigation efficiency alone, and 19 percent with efficiency and increased yields (app. table B9). Total alfalfa and sugar beet acreages both increase by 15 percent for a 20-percent increase in irrigation efficiency alone, and by 17 and 49 percent when yields also increase by 6 percent. These differences occur because a uniform relative yield increase across crops, with uniform technical change, results in differential changes in economic returns across crops.

Acreage substitutions between BoR-irrigated and groundwater-irrigated production occur only in Idaho, with or without yield-enhancing irrigation technical change (app. table B10). For Oregon and Washington, irrigation technical change promotes acreage substitutions across crops for both BoR- and groundwater-irrigated production, but these impacts do not involve water-source substitutions.

Principal crop substitutions occur in Idaho, from small grain acreage to alfalfa and sugar beet acreage, for both BoR- and groundwater-irrigated production (app. tables B11 and B12). In Oregon, corn production accounts for the largest increase in crop acres, particularly when irrigation efficiency increases yields. In Washington, irrigation technical change results in limited crop substitution effects.

Increased water prices. Policy that increases BoR water prices reduces BoR-irrigated acres and increases groundwater-irrigated acres (scenarios E1-E6, app. table B5). The aggregate effects of price increases, however, tend to be relatively small. For example, BoR-irrigated acres for the PNW decrease by 4 percent with a 10-percent increase in purchased-water costs. Water price changes also have minimal effect on total irrigated acres because producers shift from using BoR surface water to ground water. Even with water prices doubled, total irrigated acreage is reduced by less than 2 percent. Substituting water sources, however, increases future groundwater pumping costs (due to increased pumping lifts) and may result in some of these acres shifting to nonirrigated production, or even being idled.

Higher water prices reduce acreages for all BoR-irrigated crops, while acreages for all groundwater-irrigated crops increase (app. tables B6 and B7). These adjustments across water sources increase total irrigated acres slightly for some crops, but reduce total irrigated acres for other crops (app. table B5). The largest substitution effects occur with irrigated small grain and alfalfa acres. For example, a 50-percent increase in purchased-water costs reduces BoR-irrigated small grain and alfalfa acreages by 79 and 30 percent, while increasing groundwater-irrigated acres for these crops by 22 and 15 percent (app. tables B6 and B7).

Impacts of water price increases on total crop acreage allocations are mitigated by substitutions across water sources, and between irrigated and dryland production (app. tables B9 and B10). The principal water-source substitutions occur in Idaho and Washington, with more severe switching from BoR-irrigated acres to dryland crop production in Washington.

Increased BoR water prices impose different crop substitutions across States (app. tables B11-B13). The largest reductions in BoR-irrigated acreages involve alfalfa and small grain production in Idaho, corn and small grain production in Oregon, and alfalfa and corn production in Washington. The largest increases in groundwater-irrigated acreages involve alfalfa and small grain production in Idaho, and alfalfa production in Washington. The largest dryland acreage substitutions (while relatively small) involve alfalfa and small grain production in Washington.

Combined water policy options. Combining water policy choices causes significant reductions in BoR-irrigated acres and modest increases in groundwater-irrigated acres for the PNW (scenarios F1-F4, app. table B5). Total irrigated and total dryland acreage remain unaffected, except under a BoR policy-mix option, which reduces total irrigated acres slightly and increases total dryland acres slightly. Total irrigated acres decline for all field crops, except for a minor increase in small grains.

A policy-mix focus that includes increased irrigation efficiency (F1-F3) promotes sufficient groundwater substitution to outweigh reductions in total BoR-irrigated acreage. However, efficiency-based policy-mix options reduce some crop-specific irrigated acres, primarily small grains. The largest increases in irrigated acres occur with alfalfa, corn, and sugar beet production.

An efficiency-based policy-mix option reduces BoR-irrigated small grain acreage 37-81 percent for the PNW, with more modest reductions for alfalfa and other hay (app. table B6). BoR-irrigated sugar beet acres increase by as much as 40 percent. For groundwater-irrigated production, small grain acres decrease up to 30 percent, alfalfa and sugar beet acres increase up to 30 and 52 percent, and corn acres increase slightly (scenarios F2-F3, app. table B7).

For a BoR policy-mix, water-source substitutions significantly reduce BoR-irrigated acres for small grain and alfalfa production (71 and 53 percent) (scenario F4, app. table B6). The reduction in BoR-irrigated alfalfa acres is larger than under an efficiency-based policy mix. The largest decrease in groundwater-irrigated acres occurs with sugar beets, declining by 7 percent (app. table B7). Groundwater-irrigated small grain acreage increases significantly (29 percent), but not sufficiently to offset the decreases in other BoR-irrigated crop acres. Some BoR-irrigated acres switch to dryland production, principally alfalfa (app. table B8).

Total acres increase for all field crops under an efficiency-based policy mix, except for other hay, small grain, and wheat (app. table B9). Small grain acres decline the most, and sugar beet acres increase the most. A BoR policy mix mitigates impacts on crop-specific total acres, with the largest acreage reductions in alfalfa and sugar beet production (8 and 12 percent).

Uniformly applied policy-mix options promote differences across States in acreage substitutions by production category (app. table B10). For example, an efficiency-based policy-mix option (F3) reduces total BoR-irrigated acres by 14 percent for Idaho, but by only 2 percent for Oregon. Groundwater-irrigated acres increase by 7 and 6 percent for Idaho and Washington, and by less than 1 percent for Oregon. More stringently imposed policy-mix options (F1-F2) increase the differences in acreage substitutions across States.

Total acreage impacts are larger for a BoR policy mix than for an efficiency-based policy mix (app. table B10). Total BoR-irrigated acres decline by 30 percent for Idaho, and by 21 and 24 percent for Oregon and Washington. The shift of BoR-irrigated acres to dryland production is most prevalent in Idaho (9 percent).

When the policy mix increasingly emphasizes irrigation efficiency improvements (F2-F3), producers in Idaho cease producing BoR-irrigated small grains entirely, while increasing BoR-irrigated acres primarily for sugar beets (app. table B11). For Oregon, the largest BoR acreage substitutions reduce acres for small grains and increase acres for corn. For Washington, the largest BoR acreage substitutions reduce alfalfa acres, with modest reductions in small grains. For groundwater-irrigated production, an efficiency-based policy mix significantly reduces acres for small grains and significantly increases acres for alfalfa, dry beans, and sugar beets in Idaho (app. table B12). In Oregon, the largest groundwater-irrigated crop substitutions reduce acres for small grains and increase acres for corn. For Washington, these substitutions primarily increase acres for alfalfa and corn.

For a BoR policy mix, the larger BoR acreage substitutions in Idaho significantly reduce small grain and alfalfa acreage (scenario F4, app. table B11). In Oregon, BoR-irrigated acres are significantly reduced for alfalfa, corn, and small grain production, with more modest reductions for other hay and wheat. In Washington, a BoR policy mix causes larger relative decreases in BoR-irrigated acres for alfalfa. For groundwater-irrigated production, a BoR policy mix significantly increases irrigated acres for small grains in Idaho, while promoting a modest increase for small grain and alfalfa production in Oregon and Washington (app. table B12). The most significant dryland substitutions for a BoR policy mix involve BoR-irrigated acres switching to dryland alfalfa production in Idaho (app. table B13).

Policy Implications

Water policy options contribute differently to conserved agricultural water because each option differs in its effects on crop-specific economic costs. Producers respond by substituting ground water for surface water, economically profitable crops for less profitable outputs, and nonirrigated (dryland) crops for irrigated crop production. These substitutions reduce aggregate crop consumptive-use requirements, thereby increasing streamflow at the point of diversion (from surface-water irrigated agriculture) and downstream.

Agricultural water conservation under quantity-based regulatory policy is due to acreage-based substitutions. Reduced diversions of BoR surface water cause producers to significantly reduce BoR-irrigated acreage while increasing dryland crop production. At the same time, substitutions across groundwater-irrigated field crops increase total groundwater-irrigated acreage only slightly. For reduced BoR diversions of 5-20 percent, conserved agricultural water for the PNW ranges from 155,000 to 619,000 acre-feet at the farmgate. This conservation, largely reflecting reduced aggregate crop consumptive use, contributes significantly to downstream flow.

Regulatory policy that reduces BoR surface-water diversions also significantly reduces alfalfa production. Aggregate economic returns for the livestock sector are likely to decline because increased alfalfa prices and less alfalfa production affect profitability and total livestock production. However, policy change that reduces BoR diversions and also increases onfarm irrigation efficiency would eliminate the negative economic impact on the livestock sector. Increased irrigation efficiency improves the relative profitability of alfalfa, causing its production to increase, with likely positive economic impacts for the livestock sector.

Increased water prices cause producers to significantly reduce BoR-irrigated field-crop production, but increased groundwater use offsets total surface water savings. Conserved water for this policy option is due principally to water-source substitution. For water price increases of 10-100 percent, net agricultural water conserved for the PNW ranges from zero to 138,000 acre-feet, although conserved surface water ranges from 116,000 to 959,000 acre-feet. The consumptive-use quantity associated with the reduced surface-water use will significantly increase downstream flow, particularly for larger water price increases.

Improvements in off-farm water delivery and onfarm irrigation technology and water management conserve the most water among the policy options evaluated. With off-farm technical change, water conservation consists exclusively of reduced surface-water losses due to improved conveyance efficiency (that is, surface-water supplies at the farmgate are unaffected). Increasing conveyance efficiency in the PNW by 10-50 percent conserves surface water ranging from 383,000 to 1,872,000 acre-feet. The effect on downstream flow depends on the impact of increased conveyance efficiency on return flows from conveyance losses during the irrigation season. Low subsurface water-flow rates imply potentially significant downstream flow gain during the irrigation season.

For onfarm irrigation technical change, conserved ground water and surface water result from improved water-use efficiency, and crop and water-source substitutions. The larger share of water-source substitutions occurs in Idaho, with increased reliance on ground water. Policies designed to increase irrigation water-use efficiency by 10-20 percent produce total conserved water for the PNW ranging from 819,000 to 1,817,000 acre-feet.

Crop and water-source substitutions, because of increased irrigation efficiency, reduce aggregate crop consumptive use and increase streamflow at the point of diversion and downstream. Downstream flow gain is unlikely to equal the streamflow gain at the point of diversion (the conserved surface-water quantity measuring water-use efficiency and crop consumptive-use savings not diverted). Streamflow gain diminishes downstream because onfarm irrigation technical change reduces irrigation return flows. While the size of the reduced return-flow effect is uncertain, the effect will be relatively small during the irrigation season if subsurface water-flow rates are relatively low.

For irrigation technical change that is yield-enhancing, changes in relative crop profitabilities alter substitution effects, reducing aggregate conservation by reducing the impact on aggregate crop consumptive use. Total conservation for the PNW is reduced to 1,717,000 acre-feet from 1,817,000 acre-feet when policy promotes a 20-percent increase in irrigation efficiency with yields increasing 6 percent, rather than increased irrigation efficiency alone. Reduced conservation from yield-enhancing irrigation technical change means a smaller effect on downstream flow gain. Thus, public investment (or subsidy) policies intended to promote onfarm irrigation efficiency should probably focus on irrigation technical change that emphasizes reductions in irrigation waste, thereby producing larger downstream flow gain. Such technical change involves adoption of irrigation technologies that more closely coordinate water-application rates with crop consumptive-use requirements.

Policies specifying increased irrigation efficiency assumed that investment costs for onfarm technical change are fully subsidized; the subsidies are the public cost of acquiring conserved water for public reallocation goals. Positive economic returns, then, identify the aggregate producer incentive to conserve and measure the compensation due producers for the opportunity value of the conserved water to agriculture. These returns also reflect agriculture's ability to pay for the increased irrigation efficiency, while remaining as well off as before technical change. Onfarm technical change not fully subsidized reduces producer incentive to conserve, thereby inhibiting the policy's conservation potential. If policy investment costs are greater than the policy's economic returns, for a given conservation requirement, these additional costs are a minimal measure of the public (existence) value for the public good(s) derived from the conserved water.

Combining policy choices will conserve more water than any single policy choice. For general policy-mix options (which include all policy choices), total conservation for the PNW ranges from 922,000 to 1.8 million acre-feet. For a resource-efficiency policy-mix option, total conserved water amounts to 1.7 million acre-feet. Under a BoR policy-mix option, 814,000 acre-feet of surface water is conserved in the PNW, although net conserved water is 568,000 acre-feet due to groundwater substitution.

The focus of policy-mix options depends upon water policy goals. A BoR policy mix emphasizes streamflow policy goals through surface-water conservation. Alternatively, a resource-efficiency policy mix gives greater priority to groundwater quality, because producers reduce both surface-water and groundwater use.

A BoR policy mix significantly reduces surface-water use for agriculture, but increases groundwater use. Groundwater-irrigated crop substitutions mean that the conserved surface-water quantities reflect aggregate consumptive-use savings to a larger degree than would conservation for a policy mix promoting irrigation efficiency. Groundwater substitution effects also shift the source of irrigation return flows. Shifting acreage from BoR surface-water to groundwater use does not alter the return flow for that acreage, only its water source. With a BoR policy mix then, a substantial share of streamflow gain at the point of diversion is not subject to reduced return flows. Therefore, gain in downstream flow is likely to be greater than under a resource-efficiency policy mix that does affect return flows.

Policy-mix options uniformly applied throughout the Pacific Northwest do not seriously affect the distribution of impacts across States. A different water policy focus is required across PNW States if water policy goals differ across States.

Policy-mix options have several advantages over single policy reforms. Such policies enhance the flexibility of decisionmakers in formulating balanced water policy reform and allow more moderate changes in multiple policy choices to conserve water needed for reallocation goals. Combining water policies also allows decisionmakers to spread the conservation burden across producers dependent upon alternative water sources, between producers and water retailers or wholesalers (irrigation districts or the BoR), and among production regions. Policy-mix options may also promote multiple policy goals, that is, enhanced fish and wildlife habitat, enhanced water quality (surface and/or ground water), better equity in water demands, and sustainable regional agricultural economies. By combining policy choices, decisionmakers can guide water policy reform toward particular policy goals and reduce the costs of conservation associated with policy change.

Similar water policy reforms applied elsewhere in the West will also generate conserved agricultural water for reallocation. However, differences in climate, soils, topography, water sources, and water quality, which characterize crop production technology for a region, imply a difference in conservation potential for a particular water policy option. Water policy goals are also likely to differ across production regions, so water policy reforms elsewhere in the West need to be unique.

This report did not analyze the effects of institutional reforms involving water market structures, conservation disincentives promoted by restrictions on BoR water allocations and irrigation district economic profits, producer property rights to conserved water, and constraints on crop and water-source substitutions. Such institutional reforms will undoubtedly affect agricultural resource allocations, net agricultural economic returns (producer welfare), and aggregate agricultural water conservation. In particular, institutional reforms are likely to have a substantial impact on conserved agricultural water and its availability for competing water demands when implemented in conjunction with regulatory and conservation-incentive policy reforms.

Institutional arrangements to enhance water markets can take direct or indirect forms. State water banks are an indirect market form, where producers sell a share of their water allocation to a State entity responsible for reallocating or marketing the water pool to alternative users. Direct market forms, however, promote individual producer/buyer arrangements where the parties to the trade incur all transaction costs. The merits of water markets in the Pacific Northwest have been assessed using various

Data Sources

Data for WAWA were acquired from multiple secondary sources. Cost/return data for the Pacific Northwest are defined for 93 irrigated and 34 dryland field-crop production technologies. Land and water resource constraints were developed for 11 MSA's. State and hydrologic boundaries, defined on the basis of county-line approximations of major watershed divisions, were used to identify MSA's and the interregional linkages for surface-flow interactions. Given the crops in the model, observed-equilibrium acreage constraints reflect 98 and 107 percent of 1987 harvested irrigated cropland and harvested dryland cropland for the Pacific Northwest (U.S. Department of Commerce, 1989).

Yields for irrigated crops within WAWA are based on linearly homogeneous (output per unit land), reduced-form, quadratic water-yield functions (Moore, Gollehon, and Negri, 1992). These functions are reduced-form relationships derived from more general econometrically estimated yield functions using individual irrigator data from the 1984 Farm and Ranch Irrigation Survey (FRIS) for Western irrigated farms. In addition to applied water (quantity per unit land), the full yield functions incorporated qualitative variables for farm-level water management and irrigation technology options, and variables to capture physical and structural characteristics, such as weather, climate, farm structure, and soil quality. However, reduced-form relationships were generated by combining all nonirrigation water application information into a composite intercept term. Exogenous dryland yields were consistent with observed-equilibrium, modeled dryland production levels by region.

Crop-specific production costs for most crop technologies were acquired primarily from the Irrigation Production Data System (IPDS) (Schaible, Aillery, and Canning, 1989). IPDS estimates were based on a regional data series to ensure regional consistency within and across crop technologies. For the Pacific Northwest, IPDS provided cost data for all crop technologies, except for dry beans, potatoes, and sugar beets. Production cost data for non-IPDS crops were acquired primarily from State farm-level budget reports. Assumptions about onfarm water use, irrigation technology, and irrigation costs (including pumping and water purchase and distribution costs) are based on data from the 1984 FRIS, and from Soil Conservation Service (now USDA's Natural Resources Conservation Service) and State crop budgets.

Land and water data for crop-specific irrigated and dryland technologies, and aggregate resource constraints, were obtained from FRIS and BoR project records, with U.S. Census of Agriculture data serving as control totals. Land and water data were identified for dryland and irrigated production, with data for irrigated production further disaggregated into resource supplies for BoR and private production. Aggregate private-water supplies were defined as total agricultural water for the modeled crops minus BoR-supplied water. Privately supplied water consisted primarily of ground water, but also included privately supplied onfarm and off-farm surface water. Data on the share of privately supplied surface water were obtained from the Census of Agriculture. Land and water data were identified on a county-level basis and aggregated to MSA levels.

Commodity prices were calculated as exogenous expected market prices, using a geometric-lag analysis of state-level season average prices for the period 1968-83, and adjusted by a weighted-average farm program payment. Season-average crop prices were acquired from USDA's National Agricultural Statistics Service. Weighted-average deficiency payments were included to more accurately reflect farm-level returns to land and water, and relative profitability across crops. Deficiency payment adjustments were calculated using farm program data from USDA's Agricultural Stabilization and Conservation Service, now part of the reorganized USDA Consolidated Farm Service Agency.

representative-farm optimization models (Houston and Whittlesey, 1986; Hamilton, Whittlesey, and Halverson, 1989; Whittlesey and Houston, 1984). This research concludes that water markets would generate significant conserved agricultural water with minimal economic impact on the agricultural sector. Political and institutional impediments to water markets have precluded their development, but not their policy relevance. Persistent and increasing environmental, equity, and water quality concerns are likely to increase social, economic, and political pressures for institutional change. Therefore, future research assessing impacts of water markets within a restricted-equilibrium framework will enhance existing policy information.

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Appendix A - Onfarm Irrigation Technical Change: A General Analytical Perspective

Irrigation technical change improves aggregate, crop water-use efficiency with more extensive use of irrigation application systems and water-management practices that result in less surface runoff, less evaporation, and less percolation of water beyond the crop's root-zone.[1] Numerous studies indicate the economic and water-conservation merits of efficient irrigation technologies (Lee, Ellis, and Lacewell, 1985; Bernardo and others, 1987; Jensen, 1984; Homan, Skold, and Heerman, 1987; Harris and Mapp, 1986; Hornbaker and Mapp, 1988). However, the relatively slow adoption of these technologies in the Pacific Northwest implies that conservation-incentive water policies are required to promote agricultural water conservation (Schaible, Kim, and Whittlesey, 1991).

Water-saving irrigation technical change is evaluated by modifying normalized efficiency parameters for crop-specific, aggregate irrigation production technologies. Appendix figures 1 and 2 illustrate alternative production shifts for onfarm irrigation technical change and their cost effects.[2] Analysis with and without yield enhancement is necessary because of differences in crop-substitution effects.

Irrigation technical change that is only factor-augmenting (water-saving) is measured as a shift in the crop production function from T_1 to T_2, while holding yield constant at $\overline{Y}$ (app. fig. 1a). An observed-equilibrium input-output relationship (production technology) shifts from $\overline{w}$ and point A on T_1, to w^* and point B on T_2. This type of irrigation technical change assumes that producers reduce applied water, thereby increasing aggregate water-use efficiency by reducing the ratio of applied water to crop consumptive-use requirements. This technical change also assumes that the reduction in applied water is not sufficient to reduce aggregate, average crop yield. The factor-augmenting character of the aggregate technical change envisions that producers may adopt a myriad of more efficient irrigation systems and water management practices, but the aggregate irrigated-crop production technology is not likely to be transformed to an aggregate, deficit irrigation relationship.[3] Sufficient agricultural water-use inefficiency is presumed to exist, such that constant-yield, factor-augmenting technical change offers a practical policy option.[4]

Technical change that increases crop-specific, aggregate, irrigation water-use efficiency, and is output-enhancing, is identified at point D on the production surface T_3, corresponding to yield at $\overline{Y}^{**}$ in appendix figure 1b. The yield difference, $Y^{**}-\overline{Y}$, measures the per-acre output effect of increased irrigation efficiency, reflected in reduced applied water from $\overline{w}$ to w^*. Irrigation technical change may enhance output productivity because water-conserving technology either promotes increased uniformity of water distribution across a field or allows more accurate timing of water applications during critical crop growth stages, or both.

Cost effects of irrigation technical change result in changes in relative profitability of crops. This occurs because relative changes in aggregate irrigation efficiencies result in differential shifts in economic costs across crop production technologies. Appendix figure 2 illustrates the differential shifts in average and marginal economic costs, for the case of two outputs, from AEC_1 and MEC_1 to AEC_2 and MEC_2, assuming relative water-saving irrigation technical change.

Technical change also promotes crop substitution because of both relative profitability changes and differential opportunity values across crops at

[1] Data from the 1988 Farm and Ranch Irrigation Survey indicate that gravity irrigation systems were used on 36 percent and sprinkler systems on 63 percent of irrigated acres in the Pacific Northwest. However, less than 19 percent of irrigated acres involved the use of such water-conserving technologies as low-energy precision application (LEPA), low-pressure sprinkler, surge-flow, or cablegation systems (U.S. Department of Commerce, 1990). In addition, even fewer acres are irrigated using such water management techniques as soil-moisture sensing or commercial irrigation-scheduling services.

[2] The figures assume a scalar-valued, quadratic, total economic-cost function within an aggregate, multioutput production model.

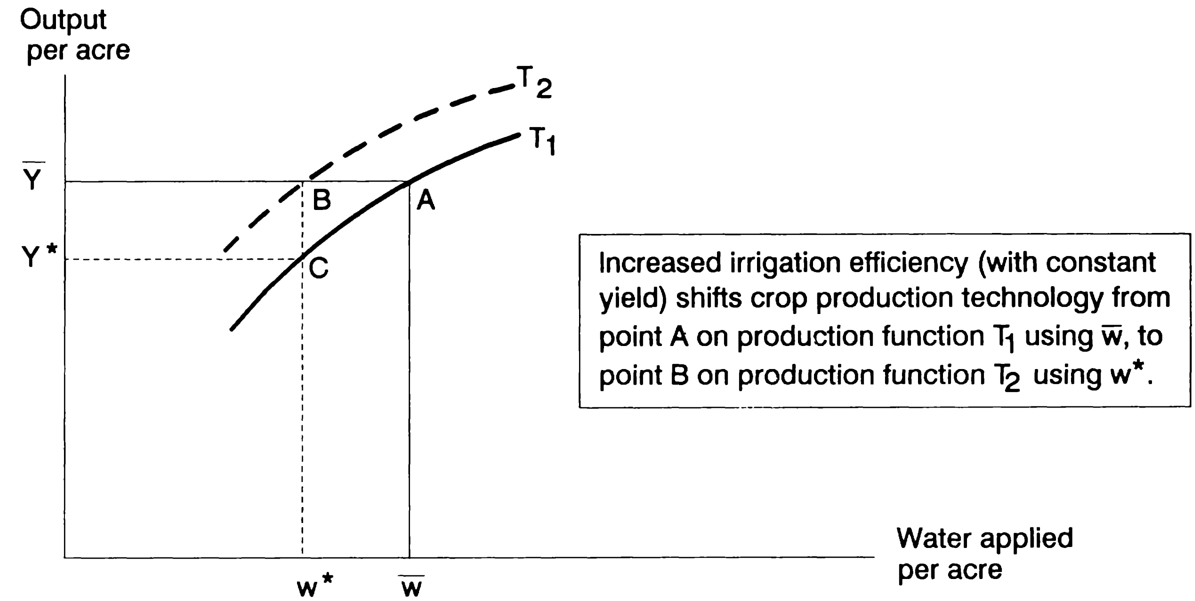
[3] Producers using deficit irrigation technology apply less water than the crop's consumptive-use requirement. However, aggregate, average applied water rates, $\overline{w}$, are greater than crop consumptive-use requirements. (See footnote 20 of text for further explanation of deficit irrigation.)

[4] Technical change involving a move from point A on T_1 to point C on T_1 (app. fig. 1a) does not reflect deficit irrigation. This technical change merely reflects producers reducing applied water rates given existing irrigation systems, resulting in reduced aggregate, average applied water rates, from $\overline{w}$ to w^*. As long as water-use inefficiency dominates irrigated crop agriculture, the aggregate production relationship will characterize constant-yield, factor-augmenting, irrigation technical change.

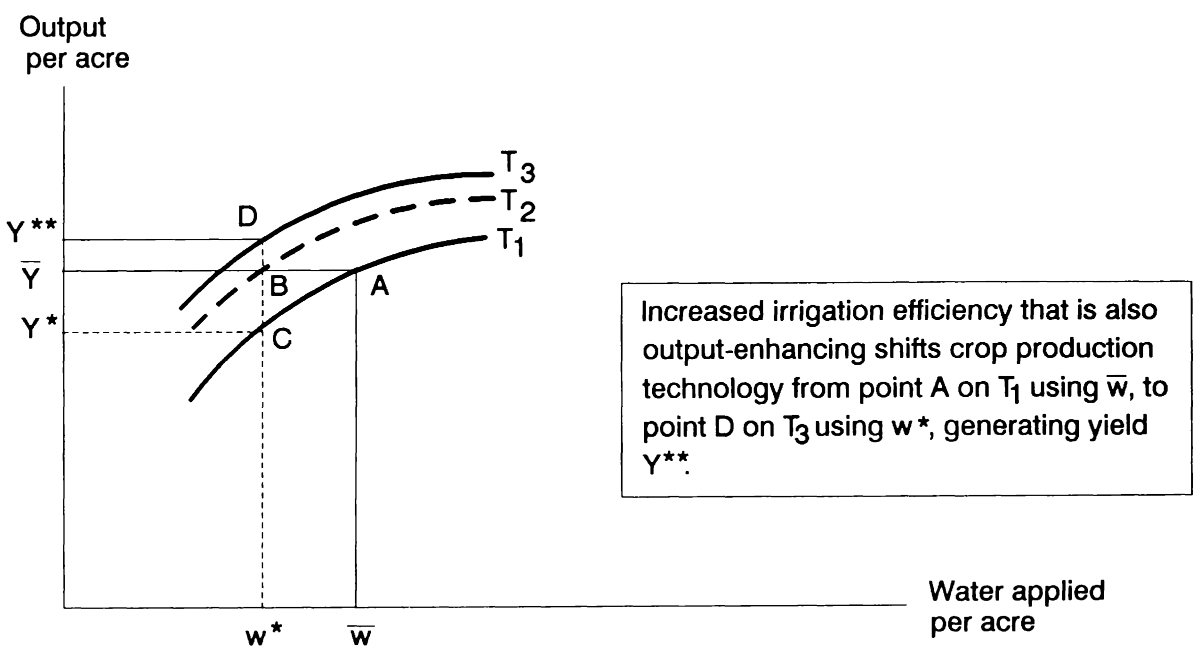
observed equilibrium, measured by the differences $(A_1 - B_1)$ and $(C_1 - D_1)$ at output levels $\bar{z}_i$ and $\bar{z}_j$. Average and marginal economic costs after technical change are defined by movements along the AEC_2 and MEC_2 cost functions, respectively, for each output. The new equilibrium, at output levels z_i^* and z_j^*,and economic costs at points A_2 and B_2, and points C_2 and D_2, reflect the cost-reducing effects of technical change and the scalar economic-cost effects of output substitution. The level of cost shifts, and the magnitude of crop substitution effects, as measured by $(z_i^* - \bar{z}_i)$ and $(z_j^* - \bar{z}_j)$, depend upon the degree of aggregate irrigation technical change across outputs.

Output-enhancing technical change generally affects relative crop profitabilities differently than does constant-output technical change. These different relative profitability effects will alter producer crop substitution possibilities and optimal fixed-resource allocations. Changing crop-specific, fixed-resource allocations will further affect economic costs, and relative crop profitabilities, as producers account for increasing (or decreasing) output-specific opportunity costs.

Appendix figure 1
Water-yield production relationships illustrating factor-augmenting technical change for onfarm, aggregate, irrigated-crop production technology



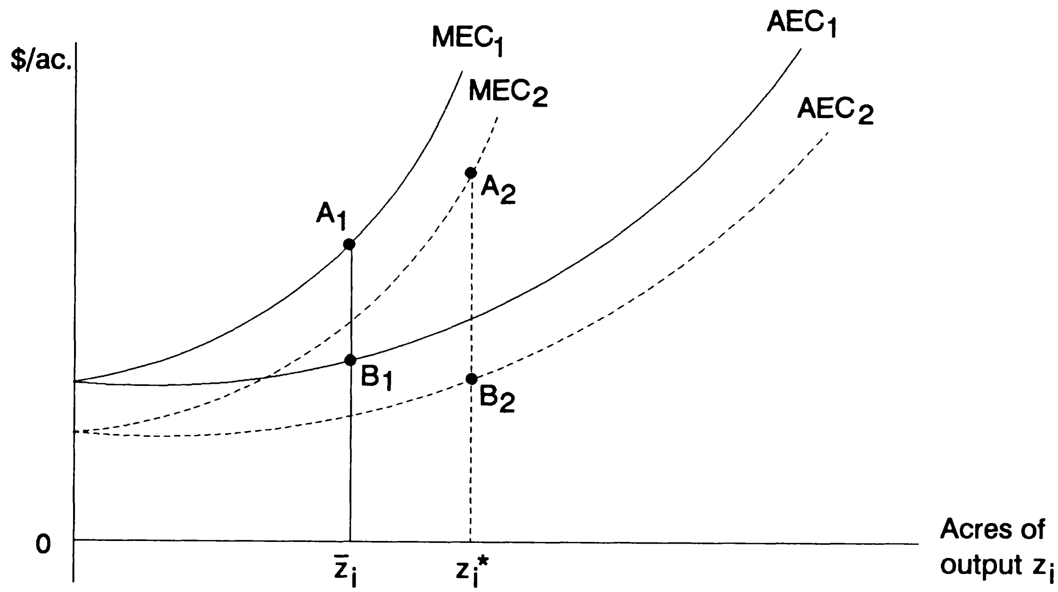
a. Factor-reducing (water-saving), constant-yield technical change



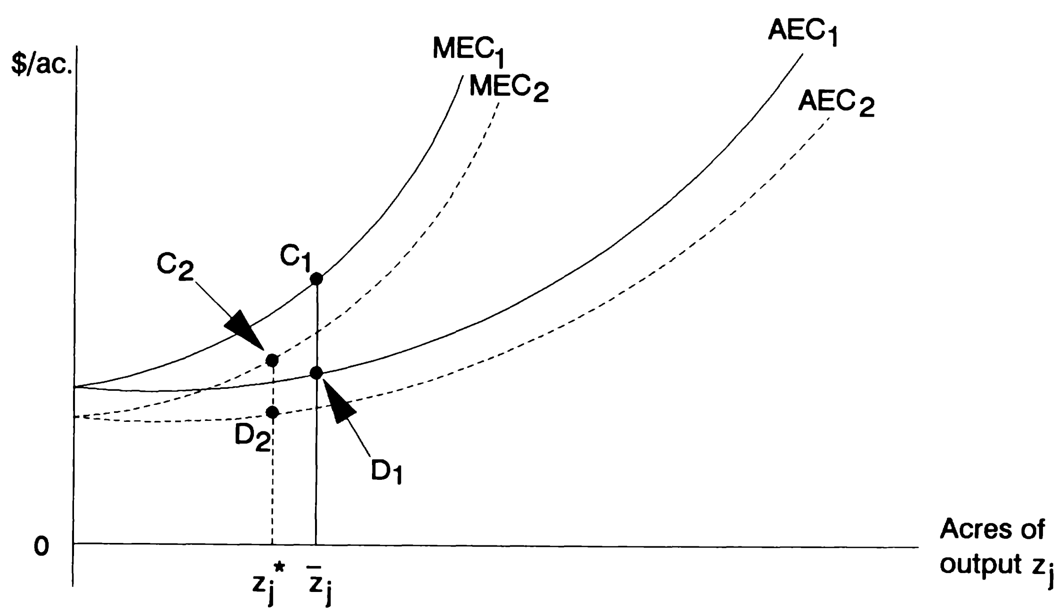
b. Factor-reducing (water-saving) and output-enhancing technical change

Appendix figure 2
Cost effects of water-saving technical change in irrigated agriculture assuming a scalar-valued quadratic total economic cost function: average economic-cost (AEC) and marginal economic-cost (MEC) curves for two crop outputs

Irrigation technical change shifts cost curves from MEC_1 and AEC_1 to MEC_2 and AEC_2, shifting equilibrium costs and output levels (indicated by acres for each output).



a. Output one:



b. Output two:

Appendix B--Water and Land Resource Allocation Impacts

Appendix table B1--Shifts in total water use by field crop and by water source for alternative water policy scenarios, Pacific Northwest

Policy option/ scenario[1]	Crop									Water source		
	Alfalfa	Corn	Dry beans	Other hay	Potatoes	Sugar beets	Small grains	Silage	Wheat	BoR	Private[2]	Total water
	Percent											
Reduced BoR diversions:												
A1: 5%	-5.0	-1.3	-1.8	-.3	-.1	-3.4	1.9	-.1	-.1	-4.9	*	-1.6
A2: 10%	-9.6	-2.6	-3.4	-.5	-.2	-6.4	2.8	-.2	-.2	-9.9	*	-3.1
A3: 15%	-14.3	-3.9	-5.0	-.7	-.2	-9.4	3.7	-.3	-.3	-14.9	*	-4.7
A4: 20%	-18.9	-5.2	-6.7	-1.0	-.3	-12.3	4.5	-.4	-.4	-19.9	*	-6.3
Onfarm technical change (increased water-use efficiency only):												
C1: 5%	5.9	-2.4	-1.3	-4.6	-4.7	4.0	-25.8	-4.7	-5.7	-5.7	-3.0	-3.8
C2: 10%	5.8	-7.3	-4.4	-9.6	-9.7	3.1	-39.7	-9.6	-10.8	-11.0	-7.1	-8.3
C3: 15%	.3	-12.7	-9.3	-14.5	-14.9	-2.5	-43.4	-14.7	-15.9	-15.6	-12.3	-13.4
C4: 20%	-5.5	-18.3	-14.2	-19.4	-20.1	-8.5	-46.6	-19.8	-21.0	-20.3	-17.6	-18.5
Onfarm technical change (increased water-use efficiency, plus yield increases):												
D1: 10% + 2%	6.8	-4.5	-2.9	-11.0	-7.9	13.5	-44.7	-8.3	-10.7	-10.7	-6.7	-7.9
D2: 15% + 4%	2.2	-7.4	-6.4	-17.2	-11.5	17.2	-52.8	-12.3	-15.7	-15.0	-11.5	-12.6
D3: 20% + 6%	-3.1	-11.0	-10.2	-23.3	-15.4	19.2	-59.1	-16.4	-20.7	-19.0	-16.8	-17.5
Purchased-water price increases:												
E1: 10%	.4	.3	-.6	.1	*	-.8	-.7	*	.1	-3.7	1.7	*
E2: 20%	1.1	.6	-1.1	.1	*	-1.1	-2.3	*	.1	-7.6	3.5	*
E3: 30%	1.7	.7	-1.5	.2	*	-1.4	-3.9	*	.2	-11.5	5.2	*
E4: 50%	2.0	.6	-2.6	.3	*	-2.1	-5.8	-.1	.4	-18.8	8.3	-.2
E5: 75%	-1.2	-.2	-4.4	.4	*	-3.4	-3.2	-.2	.2	-26.1	10.4	-1.0
E6: 100%	-2.3	-1.6	-6.2	.5	*	-4.3	-1.5	-.4	-.1	-31.2	12.3	-1.4
Combined water-policy alternatives:												
General policy-mix options--												
F1	-6.9	-5.4	-8.9	-10.7	-8.2	-.2	-18.6	-8.6	-10.2	-14.7	-6.9	-9.4
F2	-10.4	-11.5	-14.8	-23.0	-15.5	10.8	-45.0	-16.6	-20.3	-27.5	-14.1	-18.3
Resource-efficiency policy-mix option--												
F3	-5.3	-11.0	-12.7	-23.0	-15.4	16.6	-54.6	-16.5	-20.5	-25.7	-14.0	-17.7
BoR policy-mix option--												
F4	-16.2	-4.2	-7.0	-.8	-.2	-12.0	1.2	-.4	-.1	-26.4	3.7	-5.8

* = no change from baseline.

[1]Water policy scenarios are described in fig. 3.

[2]Private water sources consist of privately supplied onfarm and off-farm surface water, and groundwater supplies. Ground water is the primary share of privately supplied water.

Appendix table B2--Shifts in BoR water use by field crop for alternative water policy scenarios, Pacific Northwest

Policy option/ scenario[1]	Alfalfa	Corn	Dry beans	Other hay	Potatoes	Sugar beets	Small grains	Silage	Wheat
					Percent				
Reduced BoR diversions:									
A1: 5%	-11.1	-2.8	-2.2	-2.2	-.2	-4.2	-8.3	-.2	-.6
A2: 10%	-22.0	-5.6	-4.3	-4.4	-.3	-7.8	-18.6	-.5	-1.3
A3: 15%	-32.9	-8.3	-6.4	-6.6	-.5	-11.4	-28.8	-.7	-2.0
A4: 20%	-43.8	-11.0	-8.5	-8.9	-.7	-15.1	-39.1	-1.0	-2.7
Onfarm technical change (increased water-use efficiency only):									
C1: 5%	4.1	-2.5	-.9	-4.7	-4.7	3.7	-42.9	-4.8	-5.7
C2: 10%	3.2	-7.4	-3.9	-9.7	-9.7	2.7	-63.8	-9.7	-10.9
C3: 15%	-1.8	-12.7	-8.7	-14.7	-14.9	-2.8	-65.3	-14.8	-16.0
C4: 20%	-7.0	-18.4	-13.6	-19.7	-20.1	-8.7	-65.8	-20.0	-21.0
Onfarm technical change (increased water-use efficiency, plus yield increases):									
D1: 10% + 2%	3.6	-4.6	-2.2	-11.3	-7.9	12.6	-72.6	-8.4	-10.8
D2: 15% + 4%	-1.1	-7.5	-5.6	-17.7	-11.5	15.9	-81.2	-12.4	-15.9
D3: 20% + 6%	-6.4	-11.1	-9.3	-23.9	-15.3	17.7	-83.0	-16.5	-20.8
Purchased-water price increases:									
E1: 10%	-5.8	-.8	-1.1	-.6	-.1	-1.8	-15.5	-.1	-.4
E2: 20%	-11.4	-1.7	-2.0	-1.3	-.1	-3.2	-32.8	-.3	-.9
E3: 30%	-17.1	-2.7	-3.0	-1.9	-.2	-4.5	-50.2	-.4	-1.3
E4: 50%	-30.1	-5.1	-5.0	-3.1	-.4	-7.2	-76.8	-.7	-2.1
E5: 75%	-52.0	-9.1	-8.0	-4.8	-.6	-10.9	-77.9	-1.2	-3.6
E6: 100%	-65.5	-13.6	-10.9	-6.6	-.9	-14.3	-79.1	-1.7	-5.2
Combined water-policy alternatives:									
General policy-mix options--									
F1	-16.5	-7.2	-9.4	-11.9	-8.3	-2.1	-42.8	-9.0	-11.0
F2	-30.5	-15.1	-15.7	-25.4	-15.7	6.4	-83.5	-17.1	-21.8
Resource-efficiency policy-mix option--									
F3	-26.2	-14.2	-13.4	-25.0	-15.6	12.0	-83.3	-17.0	-22.1
BoR policy-mix option--									
F4	-53.2	-12.6	-9.7	-9.6	-.8	-16.5	-69.9	-1.2	-3.4

[1]Water policy scenarios are described in fig. 3.

Appendix table B3--Shifts in private water use by field crop for alternative water policy scenarios, Pacific Northwest[1]

Policy option/ scenario[2]	Alfalfa	Corn	Dry beans	Other hay	Potatoes	Sugar beets	Small grains	Silage	Wheat
					Percent				
Reduced BoR diversions:									
A1: 5%	-2.5	-.3	-.7	*	-.1	-2.6	5.8	*	.1
A2: 10%	-4.6	-.6	-1.4	*	-.1	-5.0	10.9	*	.3
A3: 15%	-6.6	-.8	-2.0	*	-.1	-7.3	16.0	*	.5
A4: 20%	-8.7	-1.1	-2.7	*	-.2	-9.5	21.1	-.1	.7
Onfarm technical change (increased water-use efficiency only):									
C1: 5%	6.7	-2.3	-2.0	-4.6	-4.7	4.4	-19.3	-4.6	-5.7
C2: 10%	6.8	-7.2	-5.5	-9.5	-9.7	3.5	-30.5	-9.5	-10.8
C3: 15%	1.1	-12.6	-10.5	-14.5	-14.9	-2.2	-35.2	-14.6	-15.9
C4: 20%	-4.9	-18.3	-15.5	-19.4	-20.1	-8.4	-39.3	-19.8	-21.0
Onfarm technical change (increased water-use efficiency, plus yield increases):									
D1: 10% + 2%	8.2	-4.5	-4.2	-11.0	-7.9	14.5	-34.0	-8.2	-10.6
D2: 15% + 4%	3.6	-7.4	-8.1	-17.2	-11.5	18.4	-42.0	-12.2	-15.6
D3: 20% + 6%	-1.8	-10.9	-12.2	-23.2	-15.4	20.7	-50.0	-16.4	-20.6
Purchased-water price increases:									
E1: 10%	2.9	1.1	.4	.2	.1	.3	4.9	.1	.3
E2: 20%	6.2	2.2	1.0	.3	.1	1.0	9.3	.1	.6
E3: 30%	9.5	3.1	1.5	.5	.2	1.8	13.7	.2	1.0
E4: 50%	15.2	4.7	2.5	.8	.3	3.1	21.2	.3	1.6
E5: 75%	19.6	6.0	3.3	1.1	.3	4.4	25.1	.3	2.1
E6: 100%	23.6	6.8	4.1	1.4	.4	6.0	28.0	.4	2.4
Combined water-policy alternatives:									
General policy-mix options--									
F1	-2.9	-4.1	-7.7	-10.5	-8.1	1.8	-9.4	-8.4	-9.8
F2	-2.2	-9.0	-13.1	-22.7	-15.4	15.3	-30.4	-16.3	-19.5
Resource-efficiency policy-mix option--									
F3	3.3	-8.7	-11.3	-23.0	-15.3	21.4	-43.6	-16.3	-19.8
BoR policy-mix option--									
F4	-1.0	1.6	-1.3	.3	*	-7.4	28.3	.1	1.5

* = no change from baseline.
[1]Privately supplied agricultural water consists primarily of ground water, plus some privately supplied onfarm and off-farm surface water.
[2]Water policy scenarios are described in fig. 3.

Appendix table B4--Shifts in total water use by water source for alternative water policy scenarios, Pacific Northwest (PNW)

Policy option/ scenario[1]	State	Water source BoR	Private[2]	Total water
		Percent		
Reduced BoR diversions:				
A1: 5%	Idaho	-4.9	-0.1	-1.8
	Oregon	-4.9	*	-.9
	Wash.	-4.9	*	-2.0
	PNW	-4.9	*	-1.6
A2: 10%	Idaho	-9.9	-.1	-3.6
	Oregon	-9.9	*	-1.8
	Wash.	-9.9	*	-4.0
	PNW	-9.9	*	-3.1
A3: 15%	Idaho	-14.9	-.1	-5.3
	Oregon	-14.9	*	-2.6
	Wash.	-14.9	*	-6.1
	PNW	-14.9	*	-4.7
A4: 20%	Idaho	-19.9	-.1	-7.1
	Oregon	-19.9	*	-3.5
	Wash.	-19.9	*	-8.1
	PNW	-19.9	*	-6.3
Onfarm technical change (increased water-use efficiency only):				
C1: 5%	Idaho	-6.5	-1.2	-3.1
	Oregon	-4.3	-4.6	-4.5
	Wash.	-4.7	-4.9	-4.8
	PNW	-5.7	-3.0	-3.8
C2: 10%	Idaho	-11.9	-4.5	-7.1
	Oregon	-9.3	-9.6	-9.5
	Wash.	-9.7	-9.8	-9.8
	PNW	-11.0	-7.1	-8.3
C3: 15%	Idaho	-16.4	-9.9	-12.2
	Oregon	-14.4	-14.6	-14.6
	Wash.	-14.7	-14.8	-14.8
	PNW	-15.6	-12.3	-13.4
C4: 20%	Idaho	-20.8	-15.5	-17.4
	Oregon	-19.4	-19.6	-19.6
	Wash.	-19.7	-19.9	-19.8
	PNW	-20.3	-17.6	-18.5
Onfarm technical change *(increased water-use efficiency plus yield increases)*:				
D1: 10% + 2%	Idaho	-11.6	-3.7	-6.5
	Oregon	-9.1	-9.4	-9.4
	Wash.	-9.5	-9.6	-9.6
	PNW	-10.7	-6.7	-7.9
D2: 15% + 4%	Idaho	-15.6	-8.6	-11.1
	Oregon	-13.9	-14.3	-14.2
	Wash.	-14.4	-14.5	-14.4
	PNW	-15.0	-11.5	-12.6
D3: 20% + 6%	Idaho	-18.8	-14.2	-15.8
	Oregon	-18.8	-19.2	-19.1
	Wash.	-19.3	-19.3	-19.3
	PNW	-19.0	-16.8	-17.5

Appendix table B4--Shifts in total water use by water source for alternative water policy scenarios, Pacific Northwest (PNW) - continued

Policy option/ scenario[1]	State	Water source BoR	Private[2]	Total
		Percent		
Purchased-water price increases:				
E1: 10%	Idaho	-4.7	2.6	*
	Oregon	-1.3	.3	*
	Wash.	-2.7	1.8	*
	PNW	-3.7	1.7	*
E2: 20%	Idaho	-9.6	5.3	*
	Oregon	-2.6	.6	*
	Wash.	-5.4	3.7	*
	PNW	-7.6	3.5	*
E3: 30%	Idaho	-14.5	8.0	*
	Oregon	-3.9	.8	*
	Wash.	-8.2	5.5	*
	PNW	-11.5	5.2	*
E4: 50%	Idaho	-23.0	12.7	*
	Oregon	-6.5	1.4	*
	Wash.	-15.1	8.8	-.9
	PNW	-18.8	8.3	-.2
E5: 75%	Idaho	-28.3	15.7	*
	Oregon	-9.7	2.1	*
	Wash.	-27.9	11.2	-4.6
	PNW	-26.1	10.4	-1.0
E6: 100%	Idaho	-33.5	18.5	*
	Oregon	-13.0	2.8	*
	Wash.	-33.6	12.3	-6.3
	PNW	-31.2	12.3	-1.4
General policy-mix options:				
F1	Idaho	-16.3	-5.3	-9.2
	Oregon	-10.8	-9.1	-9.4
	Wash.	-13.2	-7.3	-9.7
	PNW	-14.7	-6.9	-9.4
F2	Idaho	-29.0	-10.9	-17.4
	Oregon	-22.1	-18.6	-19.2
	Wash.	-26.7	-14.5	-19.5
	PNW	-27.5	-14.1	-18.3
Resource-efficiency policy-mix option:				
F3	Idaho	-26.2	-10.8	-16.3
	Oregon	-20.5	-18.9	-19.2
	Wash.	-26.7	-14.5	-19.5
	PNW	-25.7	-14.0	-17.7
BoR policy-mix option:				
F4	Idaho	-27.9	5.2	-6.5
	Oregon	-21.5	.7	-3.2
	Wash.	-25.6	4.9	-7.4
	PNW	-26.4	3.7	-5.8

* = no change from baseline.

[1]Water policy scenarios are described in fig. 1.

[2]Privately supplied agricultural water consists primarily of ground water, plus some privately supplied surface water.

Appendix table B5--Shifts in total irrigated acreage by field crop and by production category for alternative water policy scenarios, Pacific Northwest

Policy option/ scenario[1]	Crop									Production category			
										Irrigated			
	Alfalfa	Corn	Dry beans	Other hay	Potatoes	Sugar beets	Small grains	Silage	Wheat	BoR	Private[2]	Total irrigated	Total dryland
	Percent												
Reduced BoR diversions:													
A1: 5%	-5.0	-1.3	-1.8	-0.2	-0.1	-3.3	2.0	-0.1	-0.1	-4.9	0.3	-1.3	1.0
A2: 10%	-9.6	-2.6	-3.4	-.4	-.2	-6.3	2.9	-.2	-.1	-9.9	.5	-2.7	2.1
A3: 15%	-14.3	-3.8	-5.0	-.6	-.2	-9.2	3.8	-.3	-.2	-15.0	.8	-4.0	3.1
A4: 20%	-19.0	-5.0	-6.7	-.8	-.3	-12.2	4.7	-.4	-.3	-20.0	1.1	-5.4	4.2
Onfarm technical change (increased water-use efficiency only):													
C1: 5%	11.9	2.6	3.9	.2	.2	9.5	-22.3	.2	-.7	-2.6	1.2	*	*
C2: 10%	18.1	2.8	6.2	.1	.2	14.5	-33.6	.3	-1.0	-3.9	1.7	*	*
C3: 15%	18.6	2.5	6.8	.2	*	14.6	-34.1	.2	-1.2	-3.5	1.6	*	*
C4: 20%	18.7	1.9	7.3	.3	-.2	14.3	-33.9	.1	-1.4	-3.1	1.4	*	*
Onfarm technical change (increased water-use efficiency, plus yield increases):													
D1: 10%+2%	19.4	5.8	7.9	-1.5	2.2	26.1	-39.2	1.8	-.9	-4.2	1.9	*	*
D2: 15%+4%	21.0	8.6	10.1	-3.0	4.0	37.8	-45.2	3.1	-.9	-4.1	1.8	*	*
D3: 20%+6%	21.8	10.9	12.2	-4.6	5.7	48.9	-49.6	4.4	-1.0	-3.1	1.4	*	*
Purchased-water price increases:													
E1:10%	.4	.3	-.6	.1	*	-.7	-.7	*	.1	-4.2	1.8	*	*
E2: 20%	1.2	.6	-1.1	.2	*	-1.0	-2.4	-.1	.1	-8.5	3.7	-.1	.1
E3: 30%	1.9	.7	-1.5	.2	*	-1.3	-4.0	-.1	.2	-12.9	5.5	-.1	.1
E4: 50%	2.3	.6	-2.6	.4	*	-2.0	-5.9	-.1	.4	-20.9	8.8	-.4	.3
E5: 75%	-.8	-.2	-4.4	.5	*	-3.3	-3.4	-.2	.2	-27.7	10.9	-1.0	.7
E6: 100%	-1.8	-1.6	-6.2	.5	*	-4.2	-1.6	-.4	-.1	-32.5	12.8	-1.2	.9
Combined water-policy alternatives:													
General policy-mix options--													
F1	3.6	4.9	1.2	-1.0	1.9	10.9	-9.7	1.5	-.2	-6.8	3.0	*	*
F2	12.4	10.2	6.5	-4.1	5.5	38.5	-31.7	4.1	-.3	-13.0	5.8	*	*
Resource-efficiency policy-mix option--													
F3	19.0	10.8	9.1	-4.5	5.6	45.8	-43.9	4.2	-.8	-11.0	4.9	*	*
BoR policy-mix option--													
F4	-16.1	-4.1	-7.0	-.5	-.3	-11.8	1.3	-.4	-.1	-27.5	4.9	-5.1	3.9

* = no change from baseline.
[1]Water policy scenarios are described in fig. 3.
[2]Private irrigated acreage uses primarily ground water, plus some private onfarm and off-farm surface water.

Appendix table B6--Shifts in BoR-irrigated acreage by field crop for alternative water policy scenarios, Pacific Northwest

Policy option/scenario[1]	Alfalfa	Corn	Dry beans	Other hay	Potatoes	Sugar beets	Small grains	Silage	Wheat
					Percent				
Reduced BoR diversions:									
A1: 5%	-11.1	-2.7	-2.2	-2.0	-0.2	-4.0	-8.5	-0.2	-0.6
A2: 10%	-21.9	-5.4	-4.3	-4.0	-.3	-7.6	-18.9	-.5	-1.3
A3: 15%	-32.7	-8.0	-6.4	-6.0	-.5	-11.3	-29.4	-.7	-1.9
A4: 20%	-43.5	-10.6	-8.5	-8.0	-.7	-14.9	-39.8	-1.0	-2.6
Onfarm technical change (increased water-use efficiency only):									
C1: 5%	10.0	2.5	4.3	.1	.2	9.2	-40.7	.2	-.8
C2: 10%	15.3	2.8	6.8	.1	.2	14.1	-61.1	.2	-1.1
C3: 15%	16.2	2.5	7.4	.1	*	14.3	-60.4	.1	-1.2
C4: 20%	17.0	1.8	8.0	.1	-.2	14.1	-58.5	-.1	-1.4
Onfarm technical change (increased water-use efficiency, plus yield increases):									
D1: 10%+2%	15.8	5.8	8.6	-1.7	2.2	25.1	-71.1	1.7	-1.0
D2: 15%+4%	17.1	8.5	11.1	-3.4	4.0	36.3	-79.4	3.0	-1.1
D3: 20%+6%	17.8	10.7	13.3	-5.1	5.7	47.0	-80.3	4.3	-1.2
Purchased-water price increases:									
E1: 10%	-5.8	-.8	-1.1	-.6	-.1	-1.6	-15.8	-.1	-.4
E2: 20%	-11.4	-1.6	-2.0	-1.2	-.1	-3.0	-33.6	-.3	-.9
E3: 30%	-17.0	-2.6	-3.0	-1.8	-.2	-4.3	-51.3	-.4	-1.3
E4: 50%	-29.9	-5.0	-5.0	-2.9	-.4	-7.0	-78.5	-.7	-2.1
E5: 75%	-51.4	-8.8	-8.0	-4.5	-.6	-10.7	-79.5	-1.2	-3.6
E6: 100%	-65.1	-13.3	-10.9	-6.3	-.9	-14.1	-80.7	-1.7	-5.2
Combined water-policy alternatives:									
General policy-mix options--									
F1	-7.2	2.9	.7	-2.2	1.8	8.8	-37.2	1.1	-1.0
F2	-12.8	5.9	5.4	-6.7	5.2	33.0	-80.9	3.6	-2.2
Resource-efficiency policy-mix option--									
F3	-7.1	6.9	8.3	-6.4	5.4	40.0	-80.7	3.7	-2.6
BoR policy-mix option--									
F4	-52.7	-12.2	-9.7	-8.8	-.8	-16.3	-71.2	-1.2	-3.3

* = no change from baseline.
[1]Water policy scenarios are described in fig. 3.

Appendix table B7--Shifts in privately irrigated acreage by field crop for alternative water policy scenarios, Pacific Northwest[1]

Policy option/scenario[2]	Alfalfa	Corn	Dry beans	Other hay	Potatoes	Sugar beets	Small grains	Silage	Wheat
					Percent				
Reduced BoR diversions:									
A1: 5%	-2.6	-0.3	-0.7	*	-0.1	-2.6	5.9	*	0.2
A2: 10%	-4.7	-.6	-1.4	0.1	-.1	-4.8	11.1	*	.4
A3: 15%	-6.9	-.8	-2.0	.1	-.1	-7.1	16.3	*	.6
A4: 20%	-9.0	-1.1	-2.7	.1	-.2	-9.3	21.5	*	.8
Onfarm technical change (increased water-use efficiency only):									
C1: 5%	12.7	2.6	3.2	.2	.2	9.9	-15.3	.3	-.7
C2: 10%	19.3	2.9	5.0	.1	.2	15.0	-23.2	.4	-1.0
C3: 15%	19.5	2.6	5.3	.2	*	15.0	-24.1	.3	-1.2
C4: 20%	19.4	1.9	5.7	.3	-.2	14.5	-24.6	.1	-1.3
Onfarm technical change (increased water-use efficiency, plus yield increases):									
D1: 10%+2%	20.8	5.9	6.4	-1.5	2.2	27.2	-27.1	1.8	-.8
D2: 15%+4%	22.6	8.6	8.1	-3.0	3.9	39.3	-32.2	3.2	-.8
D3: 20%+6%	23.4	11.0	9.8	-4.5	5.6	50.9	-37.9	4.4	-.9
Purchased-water price increases:									
E1:10%	2.9	1.1	.4	.2	.1	.3	5.0	.1	.3
E2:20%	6.2	2.1	1.0	.3	.1	1.1	9.4	.1	.6
E3:30%	9.5	3.1	1.5	.5	.2	1.8	13.9	.2	1.0
E4:50%	15.3	4.6	2.5	.8	.3	3.1	21.5	.3	1.6
E5:75%	19.7	5.9	3.3	1.1	.3	4.4	25.4	.3	2.1
E6: 100%	23.8	6.7	4.1	1.4	.4	6.0	28.3	.4	2.4
Combined water-policy alternatives:									
General policy-mix options--									
F1	7.9	6.3	2.5	-.8	1.9	13.1	.7	1.7	.2
F2	22.6	13.3	8.7	-3.8	5.6	44.1	-13.0	4.5	.6
Resource-efficiency policy-mix option--									
F3	29.6	13.6	10.9	-4.3	5.8	51.7	-30.0	4.5	.1
BoR policy-mix option--									
F4	-1.3	1.6	-1.3	.5	*	-7.2	28.7	.1	1.5

* = no change from baseline.
[1]Privately irrigated acreage uses primarily ground water, plus some privately supplied onfarm and off-farm surface water.
[2]Water policy scenarios are described in fig. 3.

Appendix table B8--Shifts in dryland acreage by field crop for alternative water policy scenarios, Pacific Northwest

Policy option/ scenario[1]	Alfalfa	Corn	Dry beans	Other hay	Potatoes	Sugar beets	Small grains	Silage	Wheat
					Percent				
Reduced BoR diversions:									
A1: 5%	5.4	*	0.2	0.6	*	*	1.4	*	0.6
A2: 10%	11.2	*	.4	1.2	*	*	2.9	*	1.2
A3: 15%	17.0	*	.6	1.8	*	*	4.4	*	1.8
A4: 20%	22.8	*	.8	2.4	*	*	5.9	*	2.4
Onfarm technical change (increased water-use efficiency only):									
C1-C4:					*(Dryland cropping pattern unaffected)*				
Onfarm technical change (increased water-use efficiency, plus yield increases):									
D1 - D3:					*(Dryland cropping pattern unaffected)*				
Purchased-water price increases:									
E1: 10%	.1	*	*	*	*	*	*	*	*
E2: 20%	.5	*	*	*	*	*	.1	*	*
E3: 30%	.9	*	*	*	*	*	.1	*	*
E4: 50%	1.5	*	.1	.1	*	*	.4	*	.2
E5: 75%	1.7	*	.5	.4	*	*	1.1	*	.6
E6: 100%	1.6	*	.6	.5	*	*	1.4	*	.8
Combined water-policy alternatives:									
General and resource-efficiency policy-mix options--									
F1 - F3:					*(Dryland cropping pattern unaffected)*				
BoR policy-mix option--									
F4	21.6	*	.8	2.3	*	*	5.5	*	2.2

* = no change from baseline.
[1]Water policy scenarios are described in fig. 3.

Appendix table B9--Shifts in total acreage by field crop for alternative water policy scenarios, Pacific Northwest

Policy option/ scenario[1]	Alfalfa	Corn	Drybeans	Other hay	Potatoes	Sugar beets	Small grains	Silage	Wheat
					Percent				
Reduced BoR diversions:									
A1: 5%	-2.7	-1.3	-0.5	0.2	-0.1	-3.3	1.6	-0.1	0.4
A2: 10%	-5.1	-2.6	-1.0	.3	-.2	-6.3	2.9	-.1	.9
A3: 15%	-7.4	-3.8	-1.5	.5	-.2	-9.2	4.1	-.2	1.3
A4: 20%	-9.8	-5.0	-2.0	.7	-.3	-12.2	5.4	-.3	1.8
Onfarm technical change (increased water-use efficiency only):									
C1: 5%	9.3	2.6	1.5	.1	.2	9.5	-8.6	.2	-.2
C2: 10%	14.2	2.8	2.3	.1	.2	14.5	-13.0	.2	-.2
C3: 15%	14.5	2.5	2.5	.1	*	14.6	-13.2	.2	-.3
C4: 20%	14.6	1.9	2.7	.2	-.2	14.3	-13.1	*	-.3
Onfarm technical change (increased water-use efficiency, plus yield increases):									
D1: 10% + 2%	15.1	5.8	3.0	-.8	2.2	26.1	-15.2	1.2	-.2
D2: 15% + 4%	16.4	8.6	3.8	-1.7	4.0	37.8	-17.5	2.1	-.2
D3: 20% + 6%	17.0	10.9	4.6	-2.5	5.7	48.9	-19.2	3.0	-.2
Purchased-water price increases:									
E1: 10%	.3	.3	-.2	*	*	-.7	-.3	*	*
E2: 20%	1.0	.6	-.4	.1	*	-1.0	-.9	*	.1
E3: 30%	1.7	.7	-.6	.2	.1	-1.3	-1.5	*	.1
E4: 50%	2.1	.6	-.9	.3	.1	-2.0	-2.1	-.1	.2
E5: 75%	-.2	-.2	-1.4	.5	*	-3.3	-.6	-.2	.5
E6: 100%	-1.1	-1.6	-1.9	.5	*	-4.2	.2	-.3	.6
Combined water-policy alternatives:									
General policy-mix options--									
F1	2.8	4.9	.5	-.5	1.9	10.9	-3.7	1.0	*
F2	9.7	10.2	2.4	-2.2	5.5	38.5	-12.3	2.8	-.1
Resource-efficiency policy-mix option--									
F3	14.8	10.8	3.4	-2.5	5.6	45.8	-17.0	2.9	-.2
BoR policy-mix option--									
F4	-7.8	-4.1	-2.2	.7	-.3	-11.8	3.8	-.3	1.7

* = no change from baseline.

[1]Water policy scenarios are described in figure 3.

Appendix table B10--Shifts in total field-crop acreages by irrigated/dryland production for alternative water policy scenarios, PNW

Policy option/ scenario	State	Irrigated acres: BoR	Irrigated acres: Private	Irrigated acres: Total irrigated	Dryland acres
		Percent			
Reduced BoR diversions:					
A1: 5%	Idaho	-5.0	0.5	-1.4	2.3
	Oregon	-4.8	.1	-.8	.5
	Wash.	-4.6	*	-1.8	.6
	PNW	-4.9	.3	-1.3	1.0
A2: 10%	Idaho	-10.2	1.0	-2.9	4.7
	Oregon	-9.7	.2	-1.6	1.1
	Wash.	-9.3	*	-3.7	1.2
	PNW	-9.9	.5	-2.7	2.1
A3: 15%	Idaho	-15.5	1.4	-4.3	7.1
	Oregon	-14.6	.2	-2.4	1.7
	Wash.	-14.0	.1	-5.6	1.8
	PNW	-15.0	.8	-4.0	3.1
A4: 20%	Idaho	-20.7	1.9	-5.8	9.5
	Oregon	-19.5	.3	-3.3	2.2
	Wash.	-18.7	.1	-7.5	2.4
	PNW	-20.0	1.1	-5.4	4.2
Onfarm technical change (increased water-use efficiency only):					
C1: 5%	Idaho	-4.3	2.3	*	*
	Oregon	*	*	*	*
	Wash.	.1	*	*	*
	PNW	-2.6	1.2	*	*
C2: 10%	Idaho	-6.3	3.3	*	*
	Oregon	*	*	*	*
	Wash.	.1	*	*	*
	PNW	-3.9	1.7	*	*
C3: 15%	Idaho	-5.8	3.0	*	*
	Oregon	*	*	*	*
	Wash.	.1	*	*	*
	PNW	-3.5	1.6	*	*
C4: 20%	Idaho	-5.2	2.7	*	*
	Oregon	*	*	*	*
	Wash.	.1	*	*	*
	PNW	-3.1	1.4	*	*
Onfarm technical change (increased water-use efficiency, plus yield increases):					
D1: 10%+2%	Idaho	-6.9	3.6	*	*
	Oregon	*	*	*	*
	Wash.	.1	*	*	*
	PNW	-4.2	1.9	*	*
D2: 15%+4%	Idaho	-6.7	3.5	*	*
	Oregon	*	*	*	*
	Wash.	.1	*	*	*
	PNW	-4.1	1.8	*	*
D3: 20%+6%	Idaho	-5.1	2.7	*	*
	Oregon	*	*	*	*
	Wash.	.1	*	*	*
	PNW	-3.1	1.4	*	*
Purchased-water price increases:					
E1:10%	Idaho	-5.4	2.8	*	*
	Oregon	-1.3	.3	*	*
	Wash.	-2.6	1.7	*	*
	PNW	-4.2	1.8	*	*
E2: 20%	Idaho	-11.1	5.6	-.1	.2
	Oregon	-2.6	.6	*	*
	Wash.	-5.1	3.4	*	*
	PNW	-8.5	3.7	-.1	.1
E3: 30%	Idaho	-16.8	8.4	-.2	.4
	Oregon	-4.0	.9	*	*
	Wash.	-7.8	5.2	*	*
	PNW	-12.9	5.5	-.1	.1
E4: 50%	Idaho	-26.5	13.2	-.4	.6
	Oregon	-6.6	1.4	*	*
	Wash.	-14.2	8.3	-.7	.2
	PNW	-20.9	8.8	-.4	.3
E5: 75%	Idaho	-31.5	16.1	-.2	.3
	Oregon	-9.9	2.1	*	*
	Wash.	-26.3	10.7	-4.1	1.3
	PNW	-27.7	10.9	-1.0	.7
E6: 100%	Idaho	-36.4	18.9	*	.3
	Oregon	-13.2	2.8	*	*
	Wash.	-31.6	11.8	-5.7	1.8
	PNW	-32.5	12.8	-1.2	.9
Combined water-policy alternatives:					
General policy-mix options--					
F1	Idaho	-9.2	4.8	*	*
	Oregon	-1.8	.4	*	*
	Wash.	-3.7	2.5	*	*
	PNW	-6.8	3.0	*	*
F2	Idaho	-16.7	8.7	*	*
	Oregon	-3.9	.9	*	*
	Wash.	-8.6	5.7	*	*
	PNW	-13.0	5.8	*	*
Resource-efficiency policy-mix option--					
F3	Idaho	-13.7	7.1	*	*
	Oregon	-2.1	.4	*	*
	Wash.	-8.6	5.7	*	*
	PNW	-11.0	4.9	*	*
BoR policy-mix option--					
F4	Idaho	-30.2	7.2	-5.5	9.1
	Oregon	-21.2	1.0	-3.0	2.1
	Wash.	-24.1	4.8	-6.8	2.2
	PNW	-27.5	4.9	-5.1	3.9

Appendix table B10--Shifts in total field-crop acreages by irrigated/dryland production for alternative water policy scenarios, PNW

* = no change from baseline.
[1]Water policy scenarios are described in fig. 3.

Appendix table B11--Shift in BoR-irrigated acreage by field crop for alternative water policy scenarios, by State and the Pacific Northwest (PNW)

Policy option/ scenario[1]	State	Alfalfa	Corn	Dry beans	Other hay	Potatoes	Sugar beets	Small grains	Silage	Wheat
						Percent				
Reduced BoR diversions:										
A1: 5%	Idaho	-10.2	-1.1	-2.7	0.2	-0.2	-4.0	-10.0	-0.3	-0.2
A2: 10%		-19.9	-2.1	-5.1	.2	-.3	-7.6	-22.5	-.5	-.5
A3: 15%		-29.6	-3.1	-7.6	.3	-.5	-11.3	-34.9	-.7	-.8
A4: 20%		-39.3	-4.1	-10.1	.4	-.6	-14.9	-47.3	-1.0	-1.1
A1: 5%	Oregon	-6.0	-11.9	*	-3.5	-.3	*	-7.5	-.2	-3.2
A2: 10%		-12.0	-23.0	*	-7.1	-.6	*	-16.2	-.4	-6.6
A3: 15%		-18.0	-34.1	*	-10.7	-.9	*	-24.9	-.7	-10.7
A4: 20%		-24.0	-45.2	*	-14.2	-1.2	*	-33.6	-1.0	-13.5
A1: 5%	Washington	-15.3	-1.9	-.5	-.3	-.1	*	-.7	-.3	-.5
A2: 10%		-30.9	-3.9	-1.1	-.7	-.3	*	-1.4	-.5	-.9
A3: 15%		-46.4	-5.8	-1.6	-1.0	-.4	*	-2.0	-.8	-1.4
A4: 20%		-62.0	-7.7	-2.1	-1.3	-.6	*	-2.7	-1.0	-1.9
A1: 5%	PNW	-11.1	-2.7	-2.2	-2.0	-.2	-4.0	-8.5	-.2	-.6
A2: 10%		-21.9	-5.4	-4.3	-4.0	-.3	-7.6	-18.9	-.5	-1.3
A3: 15%		-32.7	-8.0	-6.4	-6.0	-.5	-11.3	-29.4	-.7	-1.9
A4: 20%		-43.5	-10.6	-8.5	-8.0	-.7	-14.9	-39.8	-1.0	-2.6
Onfarm technical change (increased water-use efficiency only):										
C1: 5%	Idaho	16.6	2.2	5.3	-1.9	.3	9.2	-51.6	.4	-.5
C2: 10%		25.7	3.4	8.5	-3.0	.3	14.1	-77.8	.5	-.8
C3: 15%		27.0	3.6	9.2	-3.2	.1	14.3	-77.0	.5	-.9
C4: 20%		27.8	3.7	9.9	-3.4	-.1	14.1	-74.5	.3	-1.0
C1: 5%	Oregon	2.2	9.4	*	.8	.2	*	-8.9	-1.0	-1.8
C2: 10%		2.3	10.0	*	1.0	.1	*	-9.3	-1.2	-2.0
C3: 15%		2.4	10.2	*	1.2	*	*	-9.3	-1.5	-2.2
C4: 20%		2.4	10.0	*	1.4	-.2	*	-8.9	-1.8	-2.4
C1: 5%	Washington	1.2	1.4	*	-.6	.1	*	-1.7	.1	-1.0
C2: 10%		1.8	1.2	.1	-.8	*	*	-2.0	.1	-1.2
C3: 15%		2.5	.5	.2	-1.0	-.2	*	-2.2	-.1	-1.5
C4: 20%		3.5	-.6	.3	-1.2	-.4	*	-2.3	-.3	-1.8
C1: 5%	PNW	10.0	2.5	4.3	.1	.2	9.2	-40.7	.2	-.8
C2: 10%		15.3	2.8	6.8	*	.2	14.1	-61.1	.2	-1.1
C3: 15%		16.2	2.5	7.4	.1	*	14.3	-60.4	.1	-1.2
C4: 20%		17.0	1.8	8.0	.1	-.2	14.1	-58.5	-.1	-1.4
Onfarm technical change (increased water-use efficiency, plus yield increases):										
D1: 10% + 2%	Idaho	26.8	4.6	10.7	-4.7	2.3	25.1	-89.1	1.9	-.5
D2: 15% + 4%		29.0	5.9	13.6	-6.6	4.1	36.3	-99.5	3.2	-.3
D3: 20% + 6%		30.0	7.1	16.4	-8.7	5.8	47.0	-99.5	4.4	-.2
D1: 10% + 2%	Oregon	3.5	16.5	*	-1.0	1.5	*	-15.2	.7	-1.9
D2: 15% + 4%		4.7	23.3	*	-2.7	2.7	*	21.1	2.2	-1.9
D3: 20% + 6%		5.9	29.6	*	-4.5	3.9	*	-26.7	3.8	-2.0
D1: 10% + 2%	Washington	.7	4.4	.2	-2.2	2.2	*	-4.5	1.6	-1.5
D2: 15% + 4%		.3	7.1	.4	-3.8	4.2	*	-7.1	3.0	-2.0
D3: 20% + 6%		.2	9.2	.6	-5.4	6.1	*	-9.7	4.3	-2.6

See footnotes at end of table.

--Continued

Appendix table B11--Shift in BoR-irrigated acreage by field crop for alternative water policy scenarios, by State and the Pacific Northwest (PNW)--continued

Policy option/ scenario[1]	State	Alfalfa	Corn	Dry beans	Other hay	Potatoes	Sugar beets	Small grains	Silage	Wheat
						Percent				
D1: 10% + 2%	PNW	15.8	5.8	8.6	-1.7	2.2	25.1	-71.1	1.7	-1.0
D2: 15% + 4%		17.1	8.5	11.1	-3.4	4.0	36.3	-79.4	3.0	-1.1
D3: 20% + 6%		17.8	10.7	13.3	-5.1	5.7	47.0	-80.3	4.3	-1.2
Purchased-water price increases:										
E1: 10%	Idaho	-5.7	-.5	-1.3	-.2	-.1	-1.6	-20.0	-.1	-.3
E2: 20%		-10.9	-.9	-2.4	-.6	-.2	-3.0	-42.5	-.3	-.7
E3: 30%		-16.1	-1.4	-3.5	-.9	-.2	-4.3	-65.1	-.4	-1.0
E4: 50%		-27.2	-2.3	-5.8	-1.7	-.4	-7.0	-99.5	-.7	-1.8
E5: 75%		-44.0	-3.6	-9.2	-3.1	-.6	-10.7	-99.5	-1.1	-3.1
E6: 100%		-60.5	-4.8	-12.5	-4.5	-.8	-14.1	-99.5	-1.6	-4.5
E1: 10%	Oregon	-1.5	-2.1	*	-.8	-.1	*	-3.1	-.2	-1.0
E2: 20%		-2.9	-4.2	*	-1.6	-.1	*	-6.3	-.4	-2.1
E3: 30%		-4.4	-6.5	*	-2.5	-.2	*	-9.4	-.6	-3.1
E4: 50%		-7.3	-10.7	*	-4.1	-.3	*	-15.8	-1.0	-5.2
E5: 75%		-11.0	-16.0	*	-6.2	-.5	*	-23.7	-1.5	-7.8
E6: 100%		-14.6	-21.3	*	-8.2	-.6	*	-31.7	-2.0	-10.4
E1: 10%	Washington	-8.3	-.8	-.3	-.3	-.1	*	-.8	-.1	-.5
E2: 20%		-16.6	-1.5	-.6	-.6	-.1	*	-1.5	-.2	-.9
E3: 30%		-25.3	-2.6	-.9	-.8	-.2	*	-1.9	-.3	-1.2
E4: 50%		-46.7	-5.4	-1.6	-1.2	-.4	*	-2.6	-.7	-1.7
E5: 75%		-86.6	-10.3	-3.0	-2.1	-.7	*	-4.5	-1.4	-3.0
E6: 100%		-100.0	-16.3	-4.7	-3.4	-1.2	*	-7.3	-2.1	-4.9
E1: 10%	PNW	-5.8	-.8	-1.1	-.6	-.1	-1.6	-15.8	-.1	-.4
E2: 20%		-11.4	-1.6	-2.0	-1.2	-.1	-3.0	-33.6	-.3	-.9
E3: 30%		-17.0	-2.6	-3.0	-1.8	-.2	-4.3	-51.3	-.4	-1.3
E4: 50%		-29.9	-5.0	-5.0	-2.9	-.4	-7.0	-78.5	-.7	-2.1
E5: 75%		-51.4	-8.8	-8.0	-4.5	-.6	-10.7	-79.5	-1.2	-3.6
E6: 100%		-65.1	-13.3	-10.9	-6.3	-.9	-14.1	-80.7	-1.7	-5.2
Combined water-policy alternatives:										
General policy-mix options--										
F1	Idaho	-7.0	.5	.9	-2.4	1.7	8.8	-45.4	1.1	-.3
F2		-8.1	3.3	6.8	-8.6	5.2	33.0	-99.5	3.4	-1.4
F1	Oregon	1.0	11.5	*	-2.3	1.3	*	-17.6	.6	-2.9
F2		.7	19.0	*	-7.3	3.6	*	-32.4	3.8	-4.4
F1	Washington	-11.9	2.6	-.2	-2.3	2.0	*	-4.6	1.4	-1.6
F2		-28.8	4.9	-.3	-5.7	5.8	*	-10.0	3.8	-3.0
F1	PNW	-7.2	2.9	.7	-2.2	1.8	8.8	-37.2	1.1	-1.0
F2		-12.8	5.9	5.4	-6.7	5.2	33.0	-80.9	3.6	-2.2
Resource-efficiency policy-mix option--										
F3	Idaho	1.3	4.8	10.4	-10.7	5.4	40.0	-99.5	3.7	-2.2
	Oregon	3.3	24.7	*	-6.3	3.7	*	-29.4	4.1	-3.5
	Washington	-28.8	4.5	-.3	-5.7	5.8	*	-10.0	3.8	-3.0
	PNW	-7.1	6.9	8.3	-6.4	5.4	40.0	-80.7	3.7	-2.6
BoR policy-mix option--										
F4	Idaho	-46.2	-4.6	-11.4	-.3	-.7	-16.3	-87.4	-1.2	-1.7
	Oregon	-25.7	-47.4	*	-15.2	-1.3	*	-38.0	-1.3	-14.9
	Washington	-79.5	-9.7	-2.7	-1.8	-.7	*	-3.8	-1.3	-2.6
	PNW	-52.7	-12.2	-9.7	-8.8	-.8	-16.3	-71.2	-1.2	-3.3

* = no change from baseline.

[1]Water policy scenarios are described in fig. 3.

Appendix table B12--Shift in privately irrigated acreage by field crop for alternative water policy scenarios, by State and the Pacific Northwest (PNW)[1]

Policy option/ scenario[2]	State	Alfalfa	Corn	Dry beans	Other hay	Potatoes	Sugar beets	Small grains	Silage	Wheat
						Percent				
Reduced BoR diversions:										
A1: 5%	Idaho	-4.9	-0.5	-1.1	0.5	-0.1	-2.6	7.8	-0.1	0.3
A2: 10%		-9.1	-.9	-2.1	1.0	-.1	-4.8	14.7	-.1	.5
A3: 15%		-13.2	-1.4	-3.1	1.5	-.2	-7.1	21.7	-.2	.7
A4: 20%		-17.4	-1.8	-4.0	2.0	-.2	-9.3	28.6	-.2	1.0
A1: 5%	Oregon	-.3	-.4	*	-.1	*	*	3.0	.1	.3
A2: 10%		-.6	-.8	*	-.3	*	*	5.1	.2	.5
A3: 15%		-.9	-1.1	*	-.4	*	*	7.2	.3	.7
A4: 20%		-1.1	-1.4	*	-.5	*	*	9.2	.4	.9
A1: 5%	Washington	-.1	-.2	*	*	*	*	.2	*	.1
A2: 10%		-.2	-.3	*	.1	*	*	.4	*	.2
A3: 15%		-.3	-.5	*	.1	*	*	.7	*	.3
A4: 20%		-.4	-.7	*	.1	-.1	*	.9	*	.4
A1: 5%	PNW	-2.6	-.3	-.7	*	-.1	-2.6	5.9	*	.2
A2: 10%		-4.7	-.6	-1.4	.1	-.1	-4.8	11.1	*	.4
A3: 15%		-6.9	-.8	-2.0	.1	-.1	-7.1	16.3	*	.6
A4: 20%		-9.0	-1.1	-2.7	.1	-.2	-9.3	21.5	*	.8
Onfarm technical change (for increased water-use efficiency only):										
C1: 5%	Idaho	23.7	2.1	4.7	-1.8	.3	9.9	-18.5	.3	-.6
C2: 10%		36.3	3.2	7.4	-3.2	.3	15.0	-28.9	.5	-.9
C3: 15%		36.7	3.3	7.9	-3.5	.1	15.1	-30.2	.4	-1.1
C4: 20%		36.5	3.2	8.4	-3.7	-.2	14.5	-31.0	.2	-1.3
C1: 5%	Oregon	1.9	6.0	*	.9	.1	*	-12.8	-.3	-1.1
C2: 10%		1.9	6.3	*	1.0	.1	*	-13.4	-.4	-1.2
C3: 15%		1.8	6.3	*	1.2	*	*	-13.3	-.6	-1.4
C4: 20%		1.6	5.8	*	1.4	-.2	*	-12.7	-.8	-1.6
C1: 5%	Washington	1.4	1.3	.1	-2.0	.1	*	-1.6	.6	-.8
C2: 10%		2.1	1.2	.2	-3.2	*	*	-1.8	.9	-1.0
C3: 15%		2.8	.6	.3	-3.3	-.1	*	-1.9	.8	-1.1
C4: 20%		3.7	-.3	.4	-3.5	-.4	*	-1.8	.6	-1.3
C1: 5%	PNW	12.7	2.6	3.2	.2	.2	9.9	-15.3	.3	-.7
C2: 10%		19.3	2.9	5.0	.1	.2	15.0	-23.2	.4	-1.0
C3: 15%		19.5	2.6	5.3	.2	*	15.1	-24.1	.3	-1.2
C4: 20%		19.4	1.9	5.7	-.3	-.2	14.5	-24.6	.1	-1.3
Onfarm technical change (increased water-use efficiency, plus yield increases):										
D1: 10% + 2%	Idaho	38.0	4.3	9.5	-4.9	2.3	27.2	-32.8	1.8	-.6
D2: 15% + 4%		40.0	5.5	12.0	-7.1	4.0	39.3	-38.3	3.0	-.5
D3: 20% + 6%		40.2	6.6	14.4	-9.2	5.7	50.9	-44.7	4.2	-.5
D1: 10% + 2%	Oregon	3.8	11.4	*	-.5	1.3	*	-19.6	1.3	-.7
D2: 15% + 4%		5.6	16.5	*	-1.5	2.5	*	-25.6	2.8	-.4
D3: 20% + 6%		7.4	21.2	*	-3.2	3.6	*	-31.1	4.3	-.1
D1: 10% + 2%	Washington	1.3	4.0	.3	-4.8	2.2	*	-4.5	2.2	-1.2
D2: 15% + 4%		1.3	6.2	.5	-6.6	4.2	*	-7.3	3.5	-1.7
D3: 20% + 6%		1.5	8.1	.8	-8.3	6.1	*	-9.9	4.7	-2.1
D1: 10% + 2%	PNW	20.8	5.9	6.4	-1.5	2.2	27.2	-27.1	1.8	-.8
D2: 15% + 4%		22.6	8.6	8.1	-3.0	3.9	39.3	-32.2	3.2	-.8
D3: 20% + 6%		23.4	11.0	9.8	-4.5	5.6	50.9	-37.9	4.4	-.9

Appendix table B12--Shift in privately irrigated acreage by field crop for alternative water policy scenarios, by State and the Pacific Northwest (PNW)[1]

Policy option/ scenario[2]	State	Alfalfa	Corn	Dry beans	Other hay	Potatoes	Sugar beets	Small grains	Silage	Wheat
						Percent				
Purchased-water price increases:										
E1: 10%	Idaho	4.0	.2	.4	.3	*	.3	6.8	.1	.3
E2: 20%		8.9	.4	1.0	.5	.1	1.1	12.7	.1	.5
E3: 30%		13.7	.6	1.6	.8	.1	1.8	18.6	.2	.8
E4: 50%		22.2	1.0	2.6	1.2	.2	3.1	28.6	.4	1.2
E5: 75%		28.5	1.4	3.4	1.3	.2	4.4	33.5	.5	1.5
E6: 100%		35.2	1.8	4.4	1.4	.3	6.0	37.0	.6	1.7
E1: 10%	Oregon	.3	.4	*	.2	*	*	1.0	*	.2
E2: 20%		.6	.8	*	.3	*	*	2.0	*	.4
E3: 30%		.9	1.2	*	.5	*	*	3.0	.1	.6
E4: 50%		1.6	2.2	*	.8	.1	*	4.8	.1	1.1
E5: 75%		2.3	3.3	*	1.3	.1	*	7.2	.1	1.6
E6: 100%		3.1	4.4	*	1.7	.1	*	9.5	.1	2.1
E1: 10%	Washington	6.3	1.7	.5	.2	.1	*	.7	.1	.4
E2: 20%		12.6	3.4	1.0	.3	.3	*	1.4	.1	.8
E3: 30%		18.8	4.9	1.5	.6	.4	*	2.5	.2	1.5
E4: 50%		29.4	7.1	2.4	1.0	.6	*	4.7	.2	2.7
E5: 75%		37.4	8.8	3.0	1.4	.7	*	6.4	.3	3.6
E6: 100%		42.0	9.6	3.3	1.5	.8	*	7.1	.3	4.0
E1: 10%	PNW	2.9	1.1	.4	.2	.1	.3	5.0	.1	.3
E2: 20%		6.2	2.1	1.0	.3	.1	1.1	9.4	.1	.6
E3: 30%		9.5	3.1	1.5	.5	.2	1.8	13.9	.2	1.0
E4: 50%		15.3	4.6	2.5	.8	.3	3.1	21.5	.3	1.6
E5: 75%		19.7	5.9	3.3	1.1	.3	4.4	25.4	.3	2.1
E6: 100%		23.8	6.7	4.1	1.4	.4	6.0	28.3	.4	2.4
Combined water-policy alternatives:										
General policy-mix options--										
F1	Idaho	9.7	1.5	3.3	-2.2	1.9	13.1	5.6	1.4	.6
F2		33.1	5.4	11.9	-7.2	5.6	44.1	-11.2	4.1	.8
F1	Oregon	4.1	11.4	*	-.3	1.3	*	-17.2	1.3	-.3
F2		8.0	22.3	*	-2.8	3.7	*	-26.7	4.5	.7
F1	Washington	9.8	5.8	1.0	-4.5	2.3	*	-2.7	2.3	-.3
F2		21.1	12.3	2.4	-7.4	6.4	*	-5.8	4.9	.1
F1	PNW	7.9	6.3	2.5	-.8	1.9	13.1	.7	1.7	.2
F2		22.6	13.3	8.7	-3.8	5.6	44.1	-13.0	4.5	.6
Resource-efficiency policy-mix option--										
F3	Idaho	47.3	6.9	15.2	-8.8	5.8	51.7	-34.6	4.3	*
	Oregon	7.6	22.3	*	-3.0	3.7	*	-28.8	4.4	.5
	Washington	21.1	12.3	2.4	-7.4	6.4	*	-5.8	4.9	.1
	PNW	29.6	13.6	10.9	-4.3	5.8	51.7	-30.0	4.5	.1
BoR policy-mix option--										
F4	Idaho	-6.6	-1.2	-2.6	2.3	-.1	-7.2	37.9	-.1	1.4
	Oregon	-.4	-.1	*	*	*	*	11.5	.4	1.5
	Washington	16.1	3.4	1.3	.7	.3	*	3.4	.1	1.9
	PNW	-1.3	1.6	-1.3	.5	*	-7.2	28.7	.1	1.5

* = no change from baseline.

[1]Privately irrigated acreage uses primarily ground water, plus some privately supplied onfarm and off-farm surface water.

[2]Water policy scenarios are described in fig. 3.

Appendix table B13--Shift in dryland acreage by field crop for alternative water policy scenarios, by State and the Pacific Northwest (PNW)

Policy option/ scenario[1]	State	Alfalfa	Corn	Drybeans	Other hay	Potatoes	Sugar beets	Small grains	Silage	Wheat
						Percent				
Reduced BoR diversions:										
A1: 5%	Idaho	8.6	*	*	2.1	*	*	2.0	*	1.1
A2: 10%		17.7	*	*	4.3	*	*	4.1	*	2.3
A3: 15%		26.8	*	*	6.5	*	*	6.2	*	3.5
A4: 20%		36.0	*	*	8.7	*	*	8.3	*	4.7
A1: 5%	Oregon	*	*	*	.2	*	*	1.5	*	.4
A2: 10%		*	*	*	.5	*	*	3.2	*	.8
A3: 15%		*	*	*	.7	*	*	4.9	*	1.2
A4: 20%		*	*	*	.9	*	*	6.6	*	1.6
A1: 5%	Washington	1.6	*	.3	.4	*	*	1.0	*	.5
A2: 10%		3.3	*	.7	.9	*	*	2.0	*	.9
A3: 15%		5.0	*	1.0	1.3	*	*	3.0	*	1.4
A4: 20%		6.6	*	1.4	1.7	*	*	4.0	*	1.9
A1: 5%	PNW	5.4	*	.2	.6	*	*	1.4	*	.6
A2: 10%		11.2	*	.4	1.2	*	*	2.9	*	1.2
A3: 15%		17.0	*	.6	1.8	*	*	4.4	*	1.8
A4: 20%		22.8	*	.8	2.4	*	*	5.9	*	2.4
Onfarm technical change (increased water-use efficiency only)										
C1 - C4:	All States	--[2]	--	--	--	--	--	--	--	--
Onfarm technical change (increased water-use efficiency, plus yield increases)										
D1 - D3:	All States	--	--	--	--	--	--	--	--	--
Purchased-water price increases										
E1 - E2:	Idaho	--	--	--	--	--	--	--	--	--
E3: 30%		1.5	*	*	.4	*	*	.4	*	.2
E4: 50%		2.3	*	*	.6	*	*	.5	*	.3
E5: 75%		1.0	*	*	.2	*	*	.2	*	.1
E6: 100%		--	--	--	--	--	--	--	--	--
E1 - E6:	Oregon	--	--	--	--	--	--	--	--	--
E1 - E3:	Washington	--	--	--	--	--	--	--	--	--
E4: 50%		.6	*	.1	.2	*	*	.4	*	.2
E5: 75%		3.7	*	.8	1.0	*	*	2.2	*	1.1
E6: 100%		5.0	*	1.0	1.3	*	*	3.0	*	1.4
E1 - E2:	PNW	--	--	--	--	--	--	--	--	--
E3: 30%		.9	*	*	*	*	*	.1	*	*
E4: 50%		1.5	*	.1	.1	*	*	.4	*	.2
E5: 75%		1.7	*	.5	.4	*	*	1.1	*	.6
E6: 100%		1.6	*	.6	.5	*	*	1.4	*	.8
Combined water-policy alternatives:										
General and resource-efficiency policy-mix options--										
F1 - F3:	All States	--	--	--	--	--	--	--	--	--
BoR policy-mix option--										
F4:	Idaho	34.3	*	*	8.3	*	*	7.9	*	4.5
	Oregon	*	*	*	.8	*	*	6.0	*	1.5
	Washington	6.1	*	1.2	1.6	*	*	3.6	*	1.7
	PNW	21.6	*	.8	2.3	*	*	5.5	*	2.2

* = no change from baseline.

[1]Water policy scenarios are described in fig. 3.

[2] -- indicates no dryland cropping-pattern changes (no substitution effects).

Appendix C - Hypothetical Case Study Illustrating Downstream Flow Gain/Loss due to Onfarm Irrigation Technical Change

Technical change in onfarm irrigation includes irrigation application technologies and water management practices designed to reduce water demand for crop agriculture and/or reduce water costs. Water-saving technical change in irrigation reduces the water application rate for a crop while meeting the crop's consumptive-use requirement. For irrigated agriculture using surface water, technical change reduces the need for streamflow diversions. The surface water conserved increases streamflow at the point-of-diversion. For irrigated agriculture using ground water, technical change reduces groundwater withdrawals; the ground water conserved remains in the aquifer.

The degree to which technical change in irrigation contributes to an increase in downstream flow has been a contentious issue. When technical change reduces streamflow diversions, thereby contributing to streamflow gain at the point-of-diversion, it also reduces the return flow that contributes to downstream flow from either surface runoff or aquifer percolation losses. The net effect on downstream flow, therefore, is not likely to be equivalent to the gain in streamflow at the point-of-diversion.

Ten alternative irrigation efficiency scenarios (app. table C1) reflect varying assumptions about the effect of onfarm irrigation technical change on (1) applied water, (2) surface runoff and aquifer percolation loss, and (3) aggregate crop consumptive use. In addition, return-flow options 1-5 reflect varying assumptions about the percentage of aquifer percolation loss that returns to downstream flow during the irrigation season. Furthermore, for the sake of simplicity, this analysis assumes: conveyance efficiency is an off-farm technical change issue; and surface runoff from irrigation returns to the streamflow during the irrigation season.

The effect of irrigation technical change on downstream flow is strictly zero or negative if efficiency savings are acquired entirely from reduced surface runoff or if all aquifer percolation loss returns to streamflow during the irrigation season (app. table C1). Positive downstream flows are achieved when increased efficiency in onfarm irrigation reduces aquifer percolation loss and aquifer return flows are relatively small during the irrigation season. Streamflow gains are larger for smaller aquifer return-flow rates during the irrigation season, assuming no change in aggregate crop consumptive use (scenarios #2 - #4). For similar efficiency scenarios, but assuming a 10-percent (5 acre-feet) increase in aggregate crop consumptive use, gains in downstream flow also occur when efficiency reduces aquifer percolation loss and the aquifer return-flow rate during the irrigation season is not large (scenarios #7 - #8). For scenarios assuming both increased irrigation efficiency and increased aggregate consumptive use (scenarios #9 and #10), net downstream flow effects are zero or negative, but only if the aquifer return-flow rate during the irrigation season is at least 50 percent. Since aquifer transmissivity (subsurface-flow) rates are generally small, a gain in downstream flow from conserved agricultural water is likely with technical change in onfarm irrigation.

Streamflow also gains when return flows include conveyance losses. For example, when technical change in irrigation occurs, that portion of conveyance loss that does not return to streamflow during the irrigation season becomes a gain in streamflow at the point-of-diversion and downstream.

Variability in the net streamflow gain and loss estimates suggest that area-specific hydrologic analysis would likely provide more specific information. Finally, estimates here do not include positive streamflow effects due to water-source and crop substitution effects of technical change in irrigation. Substitution effects reduce aggregate crop consumptive-use requirements, thereby increasing the gain in the downstream flow. The static approach used in this hypothetical example cannot account for substitution effects. Conservation estimates in tables 8-10, however, do account for substitution effects.

Appendix table C1--Gain/loss in downstream flow due to increased onfarm irrigation efficiency (technical change) for alternative efficiency and return-flow scenarios (a hypothetical case study)

		Alternative irrigation efficiency scenarios									
		Assuming no change in crop consumptive use[2]				Assuming increased crop consumptive use by 5 units[3]				Assuming increased crop consumptive use by 10 units + added efficiency savings[4]	
Gain/loss calculations	Base[1]	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10
						Acre-feet					
Applied agricultural water (farmgate supply)	100.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	70.0	60.0
Crop consumptive use	50.0	50.0	50.0	50.0	50.0	55.0	55.0	55.0	55.0	60.0	60.0
Surface runoff	30.0	10.0	15.0	20.0	25.0	5.0	10.0	15.0	20.0	5.0	0.0
Aquifer percolation loss	20.0	20.0	15.0	10.0	5.0	20.0	15.0	10.0	5.0	5.0	0.0
Return flow/net streamflow gain/loss calculations:											
1. Return flows assuming aquifer return-flow rate for[5]											
Option 1 = 100%	50.0	30.0	30.00	30.00	30.00	25.00	25.00	25.00	25.00	10.00	0.0
Option 2 = 75%	45.0	25.0	26.25	27.50	28.75	20.00	21.25	22.50	23.75	8.75	0.0
Option 3 = 50%	40.0	20.0	22.50	25.00	27.50	15.00	17.50	20.00	22.50	7.50	0.0
Option 4 = 25%	35.0	15.0	18.75	22.50	26.25	10.00	13.75	17.50	21.25	6.25	0.0
Option 5 = 0%	30.0	10.0	15.00	20.00	25.00	5.00	10.00	15.00	20.00	5.00	0.0
2. Direct streamflow gain (at the point of diversion) due to change in aggregate efficiency (i.e., efficiency quantity not diverted)[6]	NA	+20.0	+20.0	+20.0	+20.0	+20.0	+20.0	+20.0	+20.0	+30.00	+40.00
3. Reduced streamflows due to reductions in original return flows for[7]											
Return-flow option 1	NA	20.0	20.00	20.00	20.00	25.00	25.00	25.00	25.00	40.00	50.00
Return-flow option 2	NA	20.0	18.75	17.50	16.25	25.00	23.75	22.50	21.25	36.25	45.00
Return-flow option 3	NA	20.0	17.50	15.00	12.50	25.00	22.50	20.00	17.50	32.50	40.00
Return-flow option 4	NA	20.0	16.25	12.50	8.75	25.00	21.25	17.50	13.75	28.75	35.00
Return-flow option 5	NA	20.0	15.00	10.00	5.00	25.00	20.00	15.00	10.00	25.00	30.00
4. Net streamflow gains or losses occurring downstream for[8]											
Return-flow option 1	NA	0.0	0.0	0.0	0.0	-5.00	-5.00	-5.00	-5.00	-10.00	-10.00
Return-flow option 2	NA	0.0	+1.25	+2.50	+3.75	-5.00	-3.75	-2.50	-1.25	-6.25	-5.00
Return-flow option 3	NA	0.0	+2.50	+5.00	+7.50	-5.00	-2.50	0.0	+2.50	-2.50	0.0
Return-flow option 4	NA	0.0	+3.75	+7.50	+11.25	-5.00	-1.25	+2.50	+6.25	+1.25	+5.00
Return-flow option 5	NA	0.0	+5.00	+10.00	+15.00	-5.00	0.0	+5.00	+10.00	+5.00	+10.00

(For footnotes, see next page.)

Footnotes to Appendix Table C1:

[1]The base assumes an onfarm irrigation technology applying 100 acre-feet of water to a plot (field) of cropland. This case further assumes that crop consumption makes use of 50 acre-feet, while 30 acre-feet occurs as surface run-off and 20 acre-feet occurs as aquifer percolation. For each scenario, 100 percent of surface runoff is assumed to return to streamflow. However, alternative assumptions are made about the percent of aquifer percolation returning to streamflow. Therefore, for the base, total return flow varies depending upon the assumed aquifer return-flow rate during the irrigation season. For example, for an aquifer return-flow rate of 100 percent, total return flow equals 50 acre-feet (30 acre-feet of surface runoff plus 20 acre-feet from aquifer percolation loss). If the aquifer return-flow rate is zero during the irrigation season, then total return flow for the base equals 30 acre-feet (from surface runoff).

[2]Scenarios #1 - #4 assume that onfarm irrigation technical change reduces applied water by 20 acre-feet (from 100 to 80 acre-feet), but no change occurs in aggregate crop consumptive use. These scenarios reflect alternative assumptions about the impact of the onfarm technical change on surface runoff and aquifer percolation. Scenarios #1 - #4 were designed to initially (with #1) place the impact of onfarm efficiency on less surface runoff. Then, scenarios #2 - #4 gradually shift the impact of efficiency, placing a greater portion of the impact on reduced aquifer percolation.

[3]Scenarios #5 - #8 also assume that the onfarm irrigation technical change reduces applied water by 20 acre-feet, but these scenarios also assume that aggregate crop consumptive use increases 10 percent (from 50 to 55 acre-feet) due to increased uniformity in applied water. Initially, scenario #5 assumes that the impact of efficiency principally results in reduced surface runoff (from the base), while scenario #8 shifts the impact of efficiency to a modest reduction in surface runoff along with a more significant reduction in aquifer percolation loss.

[4]Scenarios #9 and #10 assume that the increase in aggregate consumptive use (due to increased uniformity in applied water) increases by 20 percent (10 acre-feet), and that the technical change results in a more significant reduction in applied water. Scenario #9 assumes a reduction in applied water of 30 acre-feet (100 minus 70), while scenario #10 assumes a reduction of 40 acre-feet (100 minus 60).

[5]Return-flow options 1-5 differ in the quantity of aquifer percolation loss assumed to return to streamflow (downstream from the point-of-diversion) during the irrigation season. Return-flow option 1 assumes that 100 percent of aquifer percolation loss returns to streamflow during the irrigation season. Option 2 assumes that the aquifer return-flow rate is 75 percent. Option 3 assumes a 50 percent return-flow rate. Option 4 assumes a 25 percent return-flow rate. Option 5 assumes zero return flow from aquifer percolation loss during the irrigation season.

[6]Increased irrigation efficiency results in a direct streamflow effect (gain) at the point-of-diversion. This direct effect is computed as the base-applied water, 100 acre-feet, minus scenario-applied water, 80 acre-feet, which equals 20 acre-feet (that is, irrigation efficiency savings not diverted). However, for a net downstream flow effect, this quantity must be balanced against reduced return flows associated with the technical change. Calculations for items 3 and 4 net out reduced return-flow impacts.

[7]Onfarm irrigation technical change will likely affect downstream flow as a result of reduced return flows. Reduced return flows will differ depending upon the assumption made about streamflow return quantities acquired from aquifer percolation loss, i.e., return-flow options 1-5. For example, for efficiency scenario #2 and return-flow option 2, original return flows are reduced by 18.75 acre-feet (45 acre-feet minus 26.25 acre-feet).

[8]Net streamflow gain/loss balance direct streamflow gains from onfarm irrigation technical change (gain at the point-of-diversion) against reduced streamflow returns resulting from the technical change. For example, for efficiency scenario #2 and return-flow option 2, downstream streamflow increases by 1.25 acre-feet (+20.00 acre-feet minus 18.75 acre-feet of reduced original return flows).

NA = not applicable.